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LENGTH OF UPPER EXTREMITIES IN *Homo sapiens* FROM BIRTH THROUGH ADOLESCENCE

HOWARD V. MEREDITH

Iowa Child Welfare Research Station, State University of Iowa, Iowa City, Iowa
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This paper deals with a single anthropometric trait—upper limb length—during a delimited segment of human ontogeny—the first seventeen postnatal years. It attempts to assemble, systematize, and integrate all of the research material for upper limb length presently available on North American children. Included are the findings from five investigations not previously accessible in published form.

In projecting the study, it was anticipated that the results would constitute both (a) a colligation of North American research pertaining to length of the upper extremities and (b) a contribution to several facets of scientific knowledge of particular interest to students of growth. Three of the facets on which information was sought are depicted by the following questions:

1. What is the typical course of growth for length of the upper extremities during the period from infancy through adolescence? How widely separated are the limits of normal dispersion at successive ages?

2. At what ages and by how much does the upper limb length of males exceed that of females, and *vice versa?* Are there group differences in length of the upper extremity associated with racial stock, secular period, or other variables?

3. Does the pattern of growth for length of the upper extremities differ appreciably from individual to individual? Is there greater variation in growth rate, or in the timing of rate changes, during some periods of childhood than during others?

INTRODUCTORY: THE PRENATAL PERIOD

As already declared, it is not within the scope of this paper to present a compilation and synthesis of the research to date on length of the upper extremities *prior to birth*. It does appear appropriate, however, to preface the main content of the paper with a brief sketch

of upper-limb-length growth in the embryo and fetus. Such a sketch will supply pertinent ontogenic background, and on later occasions (*e.g.*, in interpreting findings for length of the upper extremity on children born prematurely) will be found directly helpful.

No indications of the upper extremities are observable prior to the end of the third week following genesis of the human zygote. A substantial amount of evidence in support of this generalization has been amassed by Streeter ('46). Streeter describes one specimen manifesting a "trace of arm bud" at approximately three weeks after fertilization, but finds that usually the primordia of the upper limbs do not become "fairly well outlined" until the middle of the fourth week (pp. 245, 231).

At approximately one month following fertilization each upper limb "is represented by a slight swelling opposite the 5th to 8th cervical and 1st thoracic myotomes"; these swellings, or buds, "extend directly laterally" (Bardeen and Lewis, '01, pp. 4, 13). By the end of the fifth week the superior limb buds are "conspicuous projections from the body wall" which tend to be directed "somewhat caudally" (*Ibid.*, p. 5).

During the sixth week the upper extremities assume an increasingly more caudal direction and develop constrictions in the nascent elbow regions. These constrictions divide each limb into a basal (proximal) portion and a distal portion. The shoulder girdle and arm segments emerge from the basal portions, while the distal portions constitute the anlagen of the forearms and the manal segments. By the close of the week the manus has become "flattened and can be distinguished from the forearm"; the arm "still projects caudally" but the forearm and manus, "owing to flexion at the elbow," project "caudo-ventrally" (Bardeen and Lewis, '01, pp. 7-8). Upper extremity length in the representative embryo age 6 weeks approximates 0.5 cm., or one-fifth inch.

The last half of the second month is characterized by rapid increase in limb size, beginning ossification of the arm and forearm skeleton, and individuation of the digits. On each manal plate there appears a radial series of alternate swellings and depressions—four grooves interspacing five ridges. Gradually the swellings (digital precursors) elongate, and the distal sections of the depressions show greater constriction. By 8 weeks of age separation has occurred between each

digital swelling, yielding discrete fingers. It has been found by Schultz ('26) that 8 weeks after fertilization the typical length of the upper extremity approximates 1.3 cm., or one-half inch.

Pooling the findings for upper limb length from Reicher ('23) and Schultz ('26) the following averages are obtained on North American White fetuses: At the end of the first third of prenatal life (3 months after fertilization) 5.4 cm., or 2.1 inches; at the close of the second third of prenatal life 14.4 cm., or 5.7 inches; and at the termination of the fetal period 22.0 cm., or 8.7 inches. Schultz finds that at the midpoint of the prenatal period upper limb length consists of approximately 42 per cent arm length, 32 per cent forearm length, and 26 per cent manus length—the composite mean being 10.7 cm., or 4.2 inches.

The foregoing figures will be seen to indicate a gross trend of slowing growth rate with age. To illustrate: The upper extremities of the 3-month fetus are roughly 900 per cent longer than those of the embryo 7 weeks younger but only 100 per cent shorter than those of the fetus 7 weeks older.

The Neonatal Period

There are six studies which afford information for upper limb length on groups of North American infants representing postnatal ages from birth to 12 days. Four studies characterize White infants born at term, one is for full-term infants of Japanese ancestry, and one is for White infants born prematurely. In four instances the measurements were from acromiale to dactylion III and in the other two from acromiale to dactylion II.

Bakwin and Bakwin ('34) studied "sex and birth order differences at term" in the lengths of subdivisions of the upper right extremity—arm, forearm, and manus. Their means may be used to obtain values for the total length of this extremity. The subjects were 261 White infants born in New York City at the Bellevue Hospital, Fifth Avenue Hospital, New York Nursery and Child's Hospital, and New York Infirmary for Women and Children.

Description of the anthropometric procedure, covering both the landmarks employed and the limb orientation, was published in an earlier ('31) paper: The terminal landmarks were "the most lateral point of the acromial eminence" and "the tip of the middle finger";

the limb was oriented "with the arm close to the thorax and the forearm extended"; all measurements were made by one anthropometrist (Miss Allene Jones) and taken "in a plane parallel to the long axis" of the limb (p. 372).

LENGTH OF UPPER EXTREMITY (CM.) ON NEW YORK CITY NEONATES

Sex	First-born		Later-born		All birth orders	
	N	Mean	*N*	Mean	*N*	Mean
Males	71	22.2	62	22.5	133	22.3
Females	79	21.8	49	22.2	128	22.0

Inspection of these means indicates a slight tendency for the upper extremities to be shorter for newborn females than males, and shorter for first-born neonates than neonates of later birth orders. Bakwin and Bakwin found neonatal upper limb length to be apportioned approximately as follows: Arm length (acromiale to radiale) 39 per cent, forearm length (radiale to stylion) 32 per cent, and manus length (stylion to dactylion III) 29 per cent.

On 47 infants age 3 to 10 postnatal days, Richdorf ('25) collected measurements for length of the upper right limb derived as the sum of four successive "straight line" distances (arm plus forearm plus palm plus middle digit). The proximal landmark was "the lateral margin of the acromial process" and the distal landmark "the end of the middle finger" (pp. 37-39). The subjects were White infants ("majority of Northern European extraction") residing in Minneapolis, St. Paul, and Rochester, Minnesota. All were considered negative for congenital abnormality, prematurity, birth injury, and disease. Their fathers were "skilled workmen, tradesmen, or professional men" (p. 14).

LENGTH OF UPPER EXTREMITY (CM.) ON MINNESOTA URBAN INFANTS

Median Age (days)	Sex	*N*	Mean	*SD*	*V*	Percentiles 25	75	Range
7	Males	24	22.6	1.0	4.6	22.0	23.2	20.4-25.3
7	Females	23	22.3	0.9	4.1	21.7	22.9	20.9-24.0

It will be seen that (a) the mean from the male sample is slightly greater than that from the female sample, (b) the central one-half of the measurements for each sex fall within a zone of 1.2 cm.,* and

*Seventy-fifth percentile minus twenty-fifth percentile.

(c) the difference between the shortest and longest limbs of the series does not exceed 5.0 cm.

Cates and Goodwin ('36) reported analyses of neonatal data for length of the three major segments of the upper extremity—analyses which may be combined mathematically to obtain means for total length of the limb. The subjects were 665 "normal" full-term (*i.e.*, neither "premature" nor "over-term") infants "born in the Obstetrical Department of the Toronto General Hospital" during the three-year period 1933-35 (p. 433). They were examined "in a great majority of cases on the twelfth day—never earlier than the eleventh and never later than the fourteenth" (p. 438). "The upper limb was measured by tape from the tip of the middle finger . . . to the tip of the acromion" (p. 434). The measurements were made, with careful attention to their reliability, by Drs. D. Borsook, J. C. Goodwin, and D. Irwin.

LENGTH OF UPPER EXTREMITY (CM.) ON TORONTO NEONATES BORN 1933-35

Median Age (days)	Males		Females	
	N	Mean	*N*	Mean
12	340	22.8	325	22.4

These means representing the last half of the second postnatal week exceed the Bakwin and Bakwin means typifying upper limb length "at term" by 0.5 cm. for males and 0.4 for females.

Records for length of the upper extremity were accumulated by Ito ('36) on 202 full-term infants of Japanese ancestry born between 1932 and 1935 in Los Angeles, California. Approximately 56 per cent of the mothers were primiparae. The fathers were "laborers, farmers, horticulturists, clerks, small merchants, public officials and professional men. The majority were of the laboring class but were comparatively well-to-do for Japanese in California" (p. 321). Length "from the tip of the acromion process to the tip of the middle finger" was secured using "a steel tape" (p. 323). The measurements were made between birth and the seventh postnatal day, the majority being made "on the third, fourth, or fifth day" (p. 321).

UPPER EXTREMITY LENGTH (CM.) ON LOS ANGELES NEONATES OF JAPANESE ANCESTRY

Median Age (days)	Males			Females		
	N	Mean	Range	*N*	Mean	Range
4	94	19.7	18.0-23.0	108	19.8	16.5-22.3

Compared with the means for White neonates from Bakwin and Bakwin and from Richdorf, these means are smaller by 2.3 cm. to 2.8 cm. Caution must be exercised in drawing a conclusion regarding the magnitude of the difference in upper limb length between White and Mongoloid neonates. The obtained average difference of approximately one inch may be due in part to chance divergence in sampling and/or in part to a systematic variation in anthropometric procedure.*

A study of upper limb length measured as the distance "from the acromion to the tip of the second finger" was made by Taylor ('19). The subjects were 250 neonates characterized as "normal and born at term" (p. 353). They were obtained between 1914 and 1917 at the University Hospital, Minneapolis—a charity hospital admitting primiparous women almost exclusively. "Eighty-one per cent of the babies were measured on the fourth, fifth, or sixth day of life, none earlier than the second, and none later than the tenth" (p. 353). Roughly two-fifths of the mothers were of Scandinavian ancestry, two-fifths of other northwest European stocks, and one-tenth Jewish.

UPPER EXTREMITY LENGTH (CM.) ON MINNEAPOLIS NEONATES, PREDOMINANTLY FIRST-BORN

Median Age (days)	Males			Females		
	N	Mean	Range	*N*	Mean	Range
5	125	20.3	17.6-23.4	125	19.7	18.0-22.2

These means, calculated from data in which the distal landmark was dactylion II, average 2.0 cm. less than the Bakwin and Bakwin means for first-born neonates measured to dactylion III.

Talbot ('24b) collected measurements of upper limb length on 11 neonates—5 males and 6 females—"organically sound" though "premature" by 4 weeks or more (p. 30). "The criteria used in establishing prematurity were weight, stature, and general considerations, such as facies, texture of the skin, undeveloped nails, cry, unstable temperature and history of expected birth" (p. 30). When measured, the subjects varied in postnatal age from 3 to 18 days. Measurement was made "from the tip of the acromion process to the end of the second finger" (p. 555). The data were gathered 1920-22 in Boston.

*Ito's report carries no notation on the position of the limb with reference to the trunk. Bakwin and Bakwin's anthropometrist oriented the limb parallel with the long axis of the trunk. Other methods of limb orientation (*e.g.*, at right angles with the lateral wall of the trunk) shorten the straight line distance between the landmarks.

UPPER EXTREMITY LENGTH (CM.) ON NEONATES BORN PREMATURELY

Median Age (days)	N	Both sexes Mean	Range	Male Mean	Female Mean
12	11	17.8	15.5-19.8	17.9	17.7

Using as a frame of reference the mean trend for upper limb length epitomized in the introductory section, and taking cognizance of the anthropometric techniques employed, this "premature" mean of 17.8 cm. corresponds to that for normal fetuses somewhere between 4 and 6 weeks prior to the termination of prenatal life.

Taken together, the six neonatal studies reviewed are considered to support the following generalizations:

1. Average length of the upper extremity* for North American White infants approximates 22.2 cm. (8.7 inches) at term, and 22.5 cm. (8.9 inches) at 10 postnatal days. Roughly 50 per cent of the individual records cluster within 0.8 cm. (0.3 inches) of these averages, while the limits of normal variation lie in the vicinity of 2.8 cm. (1.1 inches) above and below the averages. Cast in a more convenient form for normative use, it follows that the upper limb lengths of non-pathologic White infants at birth are distributed about 25 per cent between 7.6 and 8.4 inches, 50 per cent between 8.4 and 9.0 inches, and 25 per cent between 9.0 and 9.8 inches.

2. There is a slight tendency for the upper extremity to be shorter in females than in males, and shorter in first-born children than in the aggregate of later birth orders. In each instance the average difference at birth approximates 0.4 cm., or one-sixth inch.

3. On the average, North American neonates of Japanese (Mongoloid) ancestry have shorter upper extremities than those of northwest European (White) ancestry. The magnitude of the difference apparently is more than double that for such variables as sex and birth order.

4. Organically non-pathologic neonates born 1 to 2 months prematurely tend to have markedly shorter upper extremities than neonates born at term. It must not be inferred from this that there is no overlapping of the two distributions. Although their means differ by at least an inch, the superior limbs of a few among the "premature" group are longer than those of a few among the "full-term" group.

*Distance from acromiale to dactylion III, the limb extended parallel with the lateral wall of the torso.

INFANCY

Fourteen North American investigations supply data for upper limb length at one or more ages within the period beginning two weeks after birth and extending to the end of the second year. The series encompasses research contributions made during half a century, the earliest report having been published in 1896. Unfortunately, none of the samples studied represents Negroid, Mongoloid, Mexican, American Indian, or Eskimo infants. Four of the fourteen investigations treat the growth of individual infants. Eleven afford statistical descriptions for groups of infants—in only three, however, does the description extend beyond central tendency.

Grover ('15) published means based upon 123 records for length of the upper extremity secured from physically normal infants (55 per cent males) between the postnatal ages of 5 days and 27 months. The sample was drawn in Boston: "Most of the children were among the out-patients of the Children's Hospital. . . . Some were bed patients in the wards. Others were measured at the milk stations of the Milk and Baby Hygiene Association . . . at the Boston Lying-In Hospital" or as "private patients" (p. 473). The limb "was measured by placing a broad piece of splint wood well up into the axilla; and the tip of the middle finger marked off upon the board with a pencil or the finger nail. The splint wood was always placed snugly into the axilla as far as it would go without causing discomfort. The elbow was straightened as much as possible, and the fingers extended" (p. 476).

LENGTH OF UPPER EXTREMITY (CM.) ON BOSTON INFANTS OF BOTH SEXES

	Age Group Midpoints (mos.)					
	1	3	6	12	18	24
Number of subjects	7	16	25	23	21	23
Arithmetic mean	18.0	19.3	22.0	24.9	27.5	29.9

Supplementary study was made of 13 "Mongolian idiots" measured at ages between 2 months and 2 years. While specific figures were not given, Grover showed indirectly that these subjects had superior limbs appreciably "shorter than normal."

Anthropometrically, Grover's study stands in sharp contrast with a study by Wallis ('31b). Wallis analyzed data for length of the upper extremity obtained—after orienting the arm segment parallel with the lateral thoracic wall and flexing the remainder of the limb

at right angles—as the sum of the distances from (a) the acromion to the external condyle of the humerus, and (b) the olecranon process to the tip of the middle finger.* The subjects were 77 White children (39 males, 38 females) ranging in age from 18 to 30 months, and representing American-born children of northwest European ancestry drawn predominantly from families of professional and managerial socio-economic status. All of the subjects were in attendance at the preschool laboratories of the Iowa Child Welfare Research Station between the years 1920 and 1929. For both sexes combined, Wallis' average upper limb length typifying 2 years of age approximated 42.0 cm.—a figure higher than Grover's for the same age by 12.0 cm. (upwards of four inches).

Means intermediate to those of Grover and Wallis were reported by Crum ('16). Crum analyzed measurements for length of the upper extremity taken on 7,126 infants 6 months to 2 years of age. The data were collected 1913-16 in thirty-one states at Better Babies Contests sponsored by the *Women's Home Companion* and Baby Health Conferences fostered by the American Medical Association. "The great majority of the children . . . were of American-born parents; the children, however, were of different stocks, including German, Irish, Swedish, some Italian, and some of various other races" (p. 336). Anthropometric technique was not discussed (except for a statement that the measurements were obtained "according to uniform rules"). Means were presented at monthly ages: Table 1 reproduces those for age 6 months and for succeeding quarter-year ages to 2 years.

TABLE 1
UPPER EXTREMITY LENGTH (CM.) ON "BABY CONTEST" AND "HEALTH CONFERENCE" INFANTS

Age (mos.)	Males		Females		Both sexes	
	N	Mean	*N*	Mean	*N*	Mean
6	259	26.0	176	25.1	435	25.6
9	211	27.9	183	27.3	394	27.6
12	284	29.5	228	28.6	512	29.1
15	215	31.1	197	30.1	412	30.6
18	181	32.2	178	31.2	359	31.7
21	159	33.3	142	32.7	301	33.0
24	201	34.3	160	33.7	361	34.0

*In fairness to Wallis, it should be noted: (a) she did not initiate the collection of these data, (b) she recognized the data involved duplicate use of part of the elbow region, i.e., that they did not constitute morphologically valid measures of upper limb length, and (c) she gave central tendency findings derived from them only incidentally in the process of reporting a study on changes with age in the intermembral index.

The values of Table 1 were considered standards for normal, healthy American infants. It is regrettable Crum omitted to specify the landmarks employed and the manner of limb orientation—thereby impeding their comparative usefulness. Aligned with the means from Grover and Wallis, Crum's means are approximately 4.0 cm. higher than the former and 8.0 cm. lower than the latter; it thus appears reasonable to infer that the Crum data represent some straight line distance from the region of the acromion to the tip of one of the digits. This still leaves an appreciable degree of methodological ambiguity.

Among the internal findings from Crum's study may be cited (1) the greater average limb length of males than of females by roughly 0.8 cm., and (2) the progressively smaller increment in limb length with increasing age, *e.g.*, the means from both sexes combined are higher for the end than for the beginning of the three successive semiannual intervals covered by 3.5 cm., 2.6 cm., and 2.3 cm., respectively.

Talbot ('24a) collected data for upper limb length on approximately 200 "clinically normal American children" between the postnatal ages of 2 weeks and 2 years. Accumulation of the data took place during 1915-17 on "offspring of resident normal wet-nurses," Boston Infants' Hospital. The subjects were considered "average children within the accepted normal limits of height and weight for age" and were claimed "not to represent exceptionally well nourished or poorly nourished children" (p. 541). Roughly half were males and half females. Measurements were made "from the tip of the acromion process to the end of the second finger" (p. 547).

For each sex separately, the records on every individual for age (abscissa value) and limb length (ordinate value) were "plotted on charts, and a smoothed curve drawn to indicate the trend of growth" (p. 541). Two points should be noted with the reference to these curves; they "do not represent mathematical averages" and, as published, they are difficult to read. It is estimated that the trend line for males (p. 547) passes through 25 cm. at 3 months, 28 cm. at 6 months, 32 cm. at 1 year, 35 cm. at 18 months, and 37 cm. at 2 years. The trend line for females (p. 547) appears to pass through 24 cm. at 3 months, 27 cm. at 6 months, 31 cm. at 1 year, 35 cm. at 18 months, and 38 cm. at 2 years. That these figures must be regarded as no more than crude estimates of central tendency is attested by the

fact that other graphs supposedly duplicating the findings for the early months of the first year (p. 554) yield estimates at age 3 months of 26 cm. for males and 25 cm. for females.

At postnatal ages between 4 weeks and 1 year, Richdorf ('25) amassed over 500 measures for length of the upper right limb derived as the sum of four successive "straight line" distances (arm plus forearm plus palm plus middle digit). The proximal landmark was "the lateral margin of the acromial process" and the distal landmark "the end of the middle finger" (pp. 37-39). The subjects were 350 White infants ("majority of Northern European extraction") residing in Minneapolis, St. Paul, and Rochester, Minnesota. All were considered negative for congenital abnormality, prematurity, birth injury, acute and chronic disease, and "nutritional disorder." Their fathers were "skilled workmen, tradesmen, or professional men" (p. 14). "Medical attention and instruction in child care was available for the mothers. . . . Solid food (cereal well cooked) was begun from the fourth to the seventh month, and vegetables about a month later. . . . Orange juice was given in all cases. . . . Cod liver oil and sunlight were recommended almost routinely" (pp. 15-16).

Table 2 affords the results from statistical reduction of Richdorf's data for each of 10 age-sex subgroups. Selected findings are: (1) Female infants tend to have upper extremities that are slightly shorter and less variable than those of male infants; (2) mean superior limb length is greater at age 11 months than at age 6 weeks by 7.6 cm. or 32.9 per cent in males and 7.3 cm. or 32.4 per cent in

TABLE 2
UPPER EXTREMITY LENGTH (CM.) ON MINNESOTA INFANTS OF MIDDLE AND UPPER CLASSES

Age Group						Percentiles		
Midpoint	Range	*N*	Mean	*SD*	*V*	25	75	Range
			Males					
6 wks.	4 through 7	24	23.1	1.2	5.1	22.2	23.8	21.0-26.1
3 mos.	2 through 3	49	24.4	1.3	5.5	23.5	25.2	21.1-27.7
6 mos.	5 through 6	50	27.0	1.4	5.2	26.1	27.9	23.7-29.7
9 mos.	8 through 9	49	28.9	1.4	5.0	28.0	29.9	25.8-32.6
11 mos.	10 through 11	49	30.7	1.6	5.2	29.6	31.8	27.4-34.7
			Females					
6 wks.	4 through 7	25	22.5	1.0	4.5	21.8	23.2	20.2-25.1
3 mos.	2 through 3	50	23.9	1.1	4.7	23.2	24.5	21.6-26.8
6 mos.	5 through 6	48	26.6	1.1	4.2	25.8	27.4	24.2-29.0
9 mos.	8 through 9	48	28.4	1.3	4.6	27.7	29.1	24.6-30.8
11 mos.	10 through 11	48	29.8	1.1	3.7	28.9	30.7	27.7-32.0

females; (3) the central one-half of the male measures falls within a zone of 1.6 cm. at 6 weeks, 1.8 cm. at 6 months, and 2.2 cm. at 11 months—comparable zones for females are 1.4 cm., 1.6 cm. and 1.8 cm., respectively; (4) there is marked overlapping of the distributions for successive ages, *e.g.*, some individual infants examined at age 6 weeks had upper limbs as long as other infants age 9 months. At age 6 months the length of the upper extremity was found to be about 73 per cent arm and forearm length (acromiale to level of base of thenar and hypothenar eminences) and 27 per cent hand length.

Bakwin and Bakwin ('36) reported central tendency values for the arm, forearm, and manal divisions of the upper right extremity at 8 ages during the first postnatal year. Their values, by summation, yield means for upper extremity length from "the most lateral point of the acromial eminence" to "the tip of the middle finger." Measurements were made "with the arm close to the thorax and the forearm extended" (p. 372). The data were obtained from about 1,300 examinations made on 198 White infants (94 males, 104 females) born at the Fifth Avenue Hospital, New York City, and "supervised from birth in a special clinic" for well infants. The subjects were described as mainly of North European, Mediterranean or Jewish lineage, and "from homes of moderate income" (p. 177).

Presented in Table 3 are means on each sex for the 8 age subgroups utilized by Bakwin and Bakwin, and for 4 intermediate ages. The latter were obtained by constructing central tendency curves from the former and interpolating. It will be seen that during the first postnatal year the rate of growth in upper limb length is lower for females than for males and, for both sexes, decreases with age:

TABLE 3

UPPER EXTREMITY LENGTH (CM.) ON NEW YORK INFANTS OF THE MIDDLE CLASSES

Age Group		Means for each sex		Age	Interpolated values	
Midpoint	Range (wks.)	Males	Females	(mos.)	Males	Females
2	0 through 3	22.4	22.0	1	23.1	22.5
6	4 through 7	23.7	23.0			
12	8 through 15	25.7	24.8	3	25.9	25.1
20	16 through 23	27.4	26.6			
28	24 through 31	29.1	28.3	6	28.7	27.9
36	32 through 39	30.7	29.7			
44	40 through 47	31.8	30.6	9	31.1	30.1
52	48 through 55	33.0	31.8			

During the period from 1 to 6 months the increases are 5.6 cm. (24.2 per cent) for males and 5.4 cm. (24.0 per cent) for females; between 6 and 12 months they are 4.3 cm. (15.0 per cent) for males and 3.9 cm. (14.0 per cent) for females. At 1 year of age, upper limb length was found to consist of approximately 41 per cent arm length (acromiale to radiale), 31 per cent forearm length (radiale to stylion) and 28 per cent hand length.

Compared with the means from Richdorf, those of Bakwin and Bakwin are appreciably higher. For both sexes jointly, the obtained differences at 3, 6, and 9 months are 1.3 cm., 1.5 cm., and 1.9 cm., respectively. The question arises: With what variable or combination of variables are these divergent results associated? Apparently not with socio-economic or ethnic selection—the descriptions for the two samples lend no support whatever to the view that Richdorf's infants typified either a lower economic level, or a physically smaller ancestry, than Bakwin and Bakwin's. Both studies measured the right limb and seemingly employed identical terminal landmarks, yet the possibility of some degree of systematic difference in positioning or method cannot be dismissed. There is also the possibility that at least part of the divergence found is due to factors underlying secular variation*—Richdorf's data were gathered prior to 1925, a decade earlier than those of Bakwin and Bakwin. In this connection it is relevant to add that the Crum data collected 1913-16 (which may be anthropometrically comparable with the data under examination) gave a mean at 6 months lower than the corresponding means from Richdorf and from Bakwin and Bakwin by 1.2 cm. and 2.7 cm., respectively. Further consideration of this seeming trend in the direction of increased limb length over recent decades will be deferred pending the alignment of studies for later childhood and adolescence.

Central tendency curves portraying the course of growth for upper limb length in infancy were published by Davenport ('44). They were based upon material obtained at the Normal Child Development Study, Babies' Hospital, New York City. The subjects were 34 "normal" infants (19 males, 15 females) born 1933-36 and examined

*It has been shown that North American White infants measured in the period 1910-25 were taller than those measured in the period 1926-41 by 0.5 cm. at 6 months and by more than 1.0 cm. at 1 year (Meredith '43, pp. 11-15).

at "four-week intervals" from early infancy to age 2 years. Eighty per cent were of "North European extraction" and the remainder mainly of Italian ancestry. In deriving "length of the upper limb," acromiale to stylion distance was added to "length of hand as determined from a tracing" (p. 379). The basic data were collected exclusively by the investigator, with careful attention to their reliability.

CENTRAL TENDENCY ESTIMATES FOR UPPER EXTREMITY LENGTH (CM.) ON WHITE INFANTS

Sex	Age in months 6	12	18	24
Males	26.2	30.4	33.8	36.8
Females	25.8	29.7	33.1	36.0

It must not be overlooked that this tabulation presents values read from a graph—a small graph with a fairly crude ordinate (centimeter) scale. As read, the values are above those of Crum but below those of Bakwin and Bakwin and of Richdorf. This suggests that Davenport's trends may reflect a large systematic error due to sampling, measuring or graphing; it must suffice to call attention to the small size of his sample, the lack of specificity regarding limb orientation, the fact that the same small sample was measured at each age, and the absence of any tabular presentation of results. The arm may have extended caudally and have been measured using the region immediately inferior to the acromion process as the proximal landmark. Davenport found arm length to approximate 39 per cent of upper limb length at 1 year and 40 per cent of upper limb length at 2 years.

Palmer ('44) published records for length of the left upper extremity collected 1927-29 at Minneapolis and St. Paul, Minnesota, on 14 individuals between the ages of 7 and 27 months. The subjects were "normal . . . Caucasian" infants obtained through the Institute of Child Welfare, University of Minnesota, and the Jean Martin Brown Home for Children, St. Paul. They were largely "from the upper socioeconomic classes" (pp. 121, 123). The anthropometric procedure was that of determining "shoulder height (the standard acromion-planta length)" and of subtracting from this the "linear distance from the plantar surface to the tip of the third digit of the left hand" (p. 119).

RECORDS FOR UPPER EXTREMITY LENGTH (CM.) ON 14 PHYSICALLY NORMAL WHITE INFANTS

Sex	Age in months 7	9	10		14	19	21	27
Males			34.0	33.0	33.3			35.9
			32.9	31.6				
Females	30.1	28.5	32.5	31.3		23.9	35.8	36.6
			30.0					

The 7 records at age 10 months yield a mean of 32.2 cm. Interpolated means for 10 months from other studies are: Crum, 28.1 cm.; Davenport, 28.9 cm.; Richdorf, 29.5 cm.; Bakwin and Bakwin, 31.3 cm.

Studies by Wallis ('31a) and by Simmons ('44) afford findings at age 2 years for upper limb length measured with the limb extended forward at about shoulder level. Wallis' materials, collected 1926-29 through two New York City private schools, comprised measurements of arm length on 16 children, and measurements of forearm and manus length on 37 children. The subjects were White children between the ages of 18 and 30 months (a) in attendance at the nursery school of the Bureau of Educational Experiments or the Institute of Child Development of Columbia University, (b) on the waiting list of one of these schools, or (c) "younger brothers and sisters of those attending" (p. 9). Ninety per cent had American-born parents, and over 50 per cent American-born grandparents. Socioeconomically the sample was considered representative of "the favored class whose economic environment offers them the possibility of attaining the maximum growth inherent in their family lines" (p. 12). With the limb "straight forward at shoulder level," the distances were secured from "the superior and external border on the acromion process" to "the distal end of the humerus at the radial articulation" and "from the proximal end of the radius to the tip of the middle finger" (pp. 45-46).

UPPER EXTREMITY LENGTHS (CM.) ON NEW YORK CITY "PRIVATE SCHOOL" CHILDREN

Median Age (mos.)	Sex	Arm length *N*	Arm length Mean	Forearm and manus length *N*	Forearm and manus length Mean	Total limb length Mean
24	Males	7	15.6	21	21.0	36.6
24	Females	9	14.6	16	20.0	34.6

Upper limb length was found to consist of approximately 42 per cent arm length and 58 per cent length of forearm and hand.

Simmons' data were accumulated 1931-42 on 115 children constituting "a selected sampling of the Greater Cleveland child population": All were "white" and "free from gross physical and mental defects"; the majority of their parents were "above-average both economically and educationally" and "of North European ancestry" (p. 1). Measurements were taken with the children "dressed in indoor clothing" (p. 12). "The subject stood with both upper extremities extended forward, the palms of the hands directed medially. The length of the left upper extremity was made from the inferior surface of the tip of the acromion to the tip of the middle finger" (p. 14). All examinations were scheduled "at or near the birthday" and usually the measurements were obtained by Dr. C. C. Francis or Miss R. Locher (pp. 1, 12).

UPPER EXTREMITY LENGTH (CM.) ON CLEVELAND CHILDREN OF UPPER CLASSES

Age (mos.)	Sex	*N*	Mean	*SD*	Minimum	Maximum
24	Males	61	34.6	1.5	31.3	37.9
24	Females	54	34.5	1.6	31.5	37.7

The mean for females is practically identical with that from Wallis, the mean for males below Wallis' by 2.0 cm. For both sexes together there is a difference in means of 1.0 cm., the larger mean being associated with measurements from "the superior and external border on the acromion process" and the smaller from "the inferior surface of the tip of the acromion." The difference between the shortest and longest superior limbs of the Simmons sample is 6.6 cm. Simmons found mean limb length to be composed of approximately 37 per cent arm length, 34 per cent forearm length ("from proximal to distal ends of radius"), and 29 per cent hand length.

Talbot ('24b) collected 21 records for upper limb length on 17 infants "organically sound" but "from four to ten weeks premature" (p. 30). "The criteria used in establishing prematurity were weight, stature, and general considerations, such as facies, texture of the skin, undeveloped nails, cry, unstable temperature and history of expected birth" (p. 30). The subjects were born 1920-22, and housed partly at the Boston Lying-In Hospital and partly at the Children's Depart-

ment of the Massachusetts General Hospital. When measured, they ranged in postnatal age from 14 days to 17 months. Measurement was made "from the tip of the acromion process to the end of the second finger" (p. 555).

Records were obtained on one female subject at 5 different ages, while 13 subjects were measured once each at ages between 21 and 45 postnatal days and the remaining three once each at ages 51 days, 65 days, and 16 months. Results are shown in Table 4. For the individual measured repeatedly, the record of 15.5 cm. at 2 postnatal weeks is roughly equivalent to the average for normal fetuses 8 to 10 weeks prior to term. During the 16.5 months she was followed, this infant made absolute and relative gains in upper limb length of 14.9

TABLE 4
UPPER EXTREMITY LENGTH (CM.) ON INFANTS BORN PREMATURELY

Seriatim records for a single female subject

Postnatal age (mos.):	0.5	2.2	3.2	14	17
Measurement:	15.5	16.0	20.5	28.6	30.4

Reduction of data on 13 subjects age 21 to 45 days

Median Age (mos.)	*N*	Both sexes Mean	Range	Male Mean	Female Mean
1	13	18.0	16.1-20.3	18.2	17.7

Records for 3 individuals older than 45 days

Postnatal age (mos.):	1.7	2.2	16
Measurement:	16.4	17.9	30.2

cm. and 96 per cent. These gains are appropriately placed in juxtaposition with the average increments for full-term females of 16.5 cm., 104 per cent, over the interval from 10 weeks before birth to 14 months after birth, and of 11.0 cm., 49 per cent, over the postnatal period from 2 weeks to 17 months.

The growth in upper limb length of individual infants born at term has been investigated by Hall ('96b), King ('10), and Knott and Meredith ('45). From the standpoint of the specific distances measured, these studies illustrate the gamut of differences in method.

Hall published records secured at frequent ages between 1 and 18 months on a single male infant. The child was "physically perfect" at birth and, "except for an attack of whooping-cough," enjoyed continuous "good health" (p. 331). He lived in Switzerland until 6 months of age, in Illinois after 10 months. His father's ancestry was "purely American," his mother's "purely English." The education

of both parents included "college and university studies" and both were professionally interested in child development. In Switzerland and in the United States, the child was "in the open air from one to three hours every dry day, even in the coldest weather" (p. 332).

Always the measurements were taken "with the most conscientious and painstaking exactness" (p. 333). The arm segment was positioned parallel with the lateral thoracic wall, and the remainder of the limb placed at right angles. Distances were obtained (a) "between the upper surface of the acromion process and the lower surface of the olecranon" and (b) "from the superior end of the olecranon to the tip of the third digit" (pp. 24-25).

RECORDS FOR UPPER EXTREMITY LENGTH (CM.) ON A "NORMAL AND HEALTHY" MALE INFANT

Age (mos.):	1	3	6	9	12	15	18
Measurement:	24.6	26.8	30.3	32.7	34.8	36.8	37.9

The absolute and relative gains made by this infant between ages 1 and 18 months are 13.3 cm. and 54 per cent. For the semiannual intervals 3 to 9 months and 12 to 18 months there are registered absolute increases of 5.9 cm. and 3.1 cm., while the percentage increments are 22 and 9, respectively.

Using as terminal landmarks the "crease in the arm pit" and the "end of the thumb," King obtained "regular measurements of two brothers." One boy was born in 1903, the other in 1906. Both were "apparently normal in all respects and . . . at no time had serious or protracted sickness. Their only ailments were occasional light colds and equally light attacks of measles" (p. 280). The grandparents and parents were American-born, the father was a university professor. Collection of the data occurred partly while in residence at Ann Arbor, Michigan, and partly after moving to Iowa City, Iowa. "In every case the measure was taken a number of times until it seemed that it had been obtained as accurately as it could be" (p. 282).

RECORDS FOR UPPER EXTREMITY LENGTH (CM.) ON TWO WHITE SIBLINGS (BROTHERS)

Subject	Age in months					
	1	3	6	12	18	24
A*		20.6	23.7	25.7	26.8	30.7
B**	19.7		24.8	27.8	29.4	32.0

*Subject A was studied until 6 years of age. Records beyond the infancy period

Subject B had longer upper extremities than Subject A during the entire infancy period. Between the ages of 6 months and 2 years Subject A increased 7.0 cm. or 30 per cent, and Subject B, 7.2 cm. or 29 per cent.

Knott and Meredith accumulated seriatim data for upper limb length on two physically normal siblings born 1942 (T.F.K., male), and 1943 (M.C.K., female). The grandparents were American-born and of northwest European descent; both parents were professionally trained—the father in neurophysiology and the mother in child development. Throughout infancy the children resided in Iowa City and were under the continuous guidance of one of the community's leading pediatricians.

The length of the left upper extremity was determined with wooden sliding calipers as the distance from "the most lateral point of the acromion process" to "the most distal point of the middle finger." An assistant extended the arm and forearm at the side of the body, rotated the manus so that its palmar surface faced the lateral surface of the left buttock and thigh, and extended the fingers. In application of the instrument, its shaft was kept parallel with the long axis of the limb and care was taken to guard against any tilting of the shoulder axis. Each record was derived from measurements made independently by two anthropometrists, usually Knott and Meredith.

RECORDS FOR UPPER LIMB LENGTH (CM.) ON TWO SIBLINGS OF PROFESSIONAL CLASSES

Subject	Age in months								
	1	3	6	9	12	15	18	21	24
T.F.K. (male)	21.0	23.3	26.1	28.4	30.4	32.1	33.6	35.0	36.3
M.C.K. (female)			25.4	27.8	29.8	31.5	33.0	34.4	35.7

Both series of records register a slowing rate of growth with age. Illustrative augmentations for Subject T.F.K. are 9.4 cm. or 45 per cent from 1 to 12 months, and 5.9 cm. or 19 per cent from 12 to 24 months. For Subject M.C.K., over the three successive semiannual periods 6 to 12 months, 12 to 18 months, and 18 to 24 months the absolute increases are 4.4 cm., 3.2 cm., and 2.7 cm., the percentage gains 17, 11, and 8 respectively.

Intercomparison of the various protocols on full-term infants shows

are 33.0 cm. at 3 years, 36.0 cm. at 4 years, 38.4 cm. at 5 years, and 40.2 cm. at 6 years.

**A record on Subject B was taken at 3 years; this is higher by 0.7 cm. than the corresponding record for Subject A.

Hall's subject to rank highest, King's subjects lowest, and Knott and Meredith's subjects at intermediate positions. Obviously, this placement matches the rank order of the anthropometric procedures employed. Given such heterogeneous data, it follows that comparisons of percentage gain over large segments of infancy are more valid than comparisons of absolute magnitude at selected ages. Gains between 1 and 12 postnatal months approximate 41 per cent for Hall's subject and for King's Subject B, 45 per cent for Knott and Meredith's Subject T.F.K., and 74 per cent for the premature infant studied by Talbot. Gains from 6 to 24 months approximate 30 per cent for each of King's subjects and 40 per cent for each of the subjects followed by Knott and Meredith; possible contributors to this difference include familial, secular (King's siblings were studied prior to 1910, Knott and Meredith's after 1940), and methodological variables.

All of the studies assembled for consideration in this section have now been dealt with. It remains to formulate a succinct reply to the question: What is the present status of North American research on increase in length of the upper extremities during infancy? In other words, the task remaining is one of presenting an overall synthesis of the available materials and of indicating some of the needs for further research. The numerical itemizations which follow constitute convenient media for discharging this task:

1. Over the postnatal age span from 1 month to 2 years, there is no North American research for upper limb length characterizing either infants of the various non-White ethnic groups, or White infants of low socioeconomic status. Moreover, the available investigations on White infants afford a paucity of data for the second postnatal year. Studies which treat normal variability at different infancy ages are especially meager—one study yields analyses at five selected ages between 6 weeks and 11 months, information is lacking from 1 year through 1 year 9 months, and one study reports findings for age 2 years. The problem of individual growth (of differences among individuals in growth pattern and growth rates) awaits thorough exploration—only 6 infants, 1 born prematurely and 5 at term, have been measured repeatedly over a period of a year or more.

2. Needed research on growth in superior limb length during infancy should be based on samples of sufficient size to give biologically

meaningful results, should adhere to an anthropometric procedure that is at once well specified and standardized, and should employ adequate methods of data reduction and presentation. The extant contributions, considered collectively, fall far short of fulfilling these desiderata. This is particularly regrettable in that at many points methodological inconsistencies, inadequacies, and ambiguities seriously hamper the application of such integrative devices as intercomparison, grouping, or combination of the findings from different studies.

The systematic variations found in anthropometric technique may be epitomized as follows: Proximal landmarks ranged from "upper surface of the acromion process" (Hall, '96b, Wallis, '31a) through "inferior surface of the tip of the acromion" (Simmons) to "crease in the arm pit" (King, Grover); distal landmarks were "end of the thumb" (King), "end of the second finger" (Talbot), and end of the middle finger; measurements were made on the nude limb (Knott and Meredith) and with the subjects "dressed in indoor clothing" (Simmons); limb orientation included extension "straight forward at shoulder level" (Simmons, Wallis '31a), arm segment close to the lateral thoracic wall and remainder of limb at right angles (Hall '96b, Wallis '31b), and extension of the entire limb downward parallel with the lateral wall of the trunk. Studies of infants unsatisfactory with reference to sample size include those of Grover, Palmer, and Wallis ('31a). From the standpoint of presentation of results, the most inadequate studies are those of Davenport, King, and Talbot ('24a).

3. It is estimated that—for North American White infants drawn from the upper half of the socioeconomic distribution and representing the secular period 1920-40—the average length of the upper extremity* approximates 25.1 cm. (9.9 inches) at 3 months, 27.7 cm. (10.9 inches) at 6 months, 31.6 cm. (12.4 inches) at 1 year, and 36.4 cm. (14.3 inches) at 2 years. These composite values, typifying physically normal infants of both sexes, will be found to fall slightly below the obtained averages of Bakwin and Bakwin ('36) and above those of Richdorf ('25). Taking the average at 2 years of 36.4 cm. in conjunction with the average from the previous section of 22.2 cm. at term, the increase in length of the upper extremity over the

*Distance from the most lateral point of the acromion process to the tip of the middle finger, the limb extended parallel with the lateral wall of the torso.

first two postnatal years is 14.2 cm., or 64 per cent. During the first year, the average increase approximates 9.4 cm. (3.7 inches), or 42 per cent, and during the second year, 4.8 cm. (1.9 inches), or 15 per cent.

4. The range (zone of normal variation) for upper limb length in North American White infants seemingly approximates 5.5 cm. (2.2 inches) at birth, 6.0 (2.4 inches) at 6 months, 6.5 cm. (2.6 inches) at 1 year, and 7.0 cm. (2.8 inches) at 2 years. At corresponding ages, estimates for the interquartile distance (that portion of the range encompassing the central one-half of the individual measures) are 1.6 cm. (0.6 inches), 1.8 cm. (0.7 inches), 2.0 cm. (0.8 inches) and 2.3 or (0.9 inches), respectively. As already made clear, these series of variability figures are derived from meager amounts of data; they are presented only as tentative values for normative use pending the availability of more substantial analyses.

5. The upper extremities of the average male infant are slightly longer than those of the average female infant. Ample support of this generalization is found in the investigations of Crum, Richdorf, Bakwin and Bakwin, and others. The magnitude of the difference between the average male and female is about 0.4 cm. at birth, 0.6 cm. at 3 to 6 months, and 0.9 cm. during the second year. Richdorf, in his study covering the first postnatal year, found female infants to be slightly less variable in superior limb length than male infants.

6. There is evidence suggesting that length of the upper extremity has tended to increase during recent decades. At age 6 months, three series of measurements gathered around 1914 (Crum), 1924 (Richdorf), and 1934 (Bakwin and Bakwin) yield means of 25.6 cm., 26.8 cm., and 28.3 cm. While the increases manifested may accrue in part from sampling and/or from differences in procedure, they also may register the operation of some genetic or environmental variable(s) to produce a rising secular trend.

7. Grover reported measuring 13 "Mongolian idiots" at various infancy ages and finding them to have upper extremities "shorter than normal." Thirteen "premature" infants were examined by Talbot at about 1 month after birth and found to have markedly shorter upper extremities than full-term infants of the same age. Knott and Meredith took frequent measurements of upper limb length on two

siblings and obtained individual growth curves similar in form to the trend line drawn through averages. For a single infant born prematurely by several weeks, Talbot found rate of growth in upper limb length during the first postnatal year to be appreciably higher than growth rates in full-term infants.

Childhood and Adolescence

There are fourteen separate studies presently available which pertain to length of the upper extremities in North American children between the ages of 3 and 17 years. Two of these studies do not extend beyond age 6 years, four encompass the entire period from 3 to 17 years, four extend from 3 years to between 8 and 12 years, for one the delimiting ages are 6 and 17 years, and three have reference only to ages above 9 years. In four instances data are analyzed for males only, while the remaining ten investigations present findings on each sex. All of the investigations afford central tendency values, five provide information on variability, and two treat individual growth (one each the growth of pathologic and nonpathologic individuals).

Crum ('16) reported means for upper limb length derived from measurement of 3,000 children between the ages of 26 and 48 months. The data were collected 1913-16 in thirty-one states at Better Babies Contests sponsored by the *Women's Home Companion* and Health Conferences fostered by the American Medical Association. "The great majority of the children . . . were of American-born parents; the children, however, were of different stocks, including German, Irish, Swedish, some Italian, and some of various other races" (p. 336). Neither the landmarks employed nor the manner of limb orientation were specified. It is probable—as shown in the previous section—that the proximal landmark was in the vicinity of the acromion (rather than the axilla) and that the limb was extended (not flexed at the elbow and measured in a manner involving duplicate use of part of the elbow region).

Means were given at monthly intervals: Table 5 reproduces those for semiannual ages from 2.5 years to 4 years. These values were considered standards for normal, healthy American children. On the one hand, the racial composition of the sample would tend to make it more representative than if children of northwest European

TABLE 5
LENGTH OF UPPER EXTREMITY (CM.) ON CHILDREN MEASURED AT HEALTH CONFERENCES

Age (yrs.)	Males		Females		Both sexes	
	N	Mean	*N*	Mean	*N*	Mean
2.5	153	36.5	132	35.6	285	36.1
3.0	76	38.4	90	37.1	166	37.7
3.5	27	39.7	42	39.1	69	39.3
4.0	19	40.6	31	40.0	50	40.2

ancestry only had been included. On the other hand, there seems little doubt that the children brought to health conferences and "baby shows" (at many of which prizes were given) predominantly would be healthy and well developed.

Measurements of the left and right upper extremities on children between the ages of 34 and 74 months were amassed and analyzed by the physical growth staff of the Iowa Child Welfare Research Station ('29). The subjects—150 males and 167 females—were American-born White children "in good health" (p. 541). They were almost exclusively children of northwest European ancestry drawn from "the rather favoring social environment provided by parents of the professional and merchant classes" (p. 541). All were measured between 1920 and 1928 while enrolled in the Station's preschool laboratories.* Measurements were made on the nude subject after orienting each arm segment parallel with the lateral thoracic wall and flexing the remaining portion of each limb at right angles. The distances determined were "from the acromion to the external condyle of the humerus" and "from the olecranon process to the finger tip" (middle digit).

Analyses were made representing each quarterly age between 3 and 6 years. Table 6 reproduces the results at semiannual intervals. Selected findings are: (1) The male means exceed the female means at every age from 3.5 years to 6 years—the average difference between comparable figures for the two sexes is 1.2 cm.; (2) the means for males at 6 years are higher than those at 3 years by 9.4 cm., or a full 20 per cent; and (3) the right limb shows a tendency to be slightly longer than the left—while there is only the barest trace of a difference, it is expressed fairly consistently.

*Attention is called to two other references. Baldwin and Stecher ('24) published a preliminary reduction of some of these data. All of the data were later utilized by Wallis ('31b) in a paper whose major objective was that of studying age changes in the intermembral index.

TABLE 6
MEAN LENGTH OF UPPER EXTREMITIES (CM.) ON WHITE "PRIVATE SCHOOL" CHILDREN

Age group Midpoint (yrs.)	Range (mos.)	Males N	Left	Right	Females N	Left	Right
3.0	34.5-37.5	21	45.5	45.6	31	45.5	45.4
3.5	40.5-43.5	32	47.7	47.7	35	46.3	46.4
4.0	46.5-49.5	29	49.3	49.4	40	47.9	48.0
4.5	52.5-55.5	45	51.0	51.0	46	49.4	49.5
5.0	58.5-61.5	50	52.3	52.4	52	51.2	51.2
5.5	64.5-67.5	54	53.9	54.0	47	52.7	52.8
6.0	70.5-73.5	36	54.9	55.0	31	53.6	53.7

Materials were published by Wallis ('31a) from which may be derived means for length of upper extremity at ages 3 to 8 years. The basic data were collected in New York City 1926-29 on White children representing "the favored class whose economic environment offers them the possibility of attaining the maximum growth inherent in their family lines" (p. 12). With the upper extremity "held straight forward at shoulder level," measurement was made (a) from "the superior and external border on the acromion process" to "the distal end of the humerus at the radial articulation" and (b) 'from the proximal end of the radius to the tip of the middle finger" (pp. 45-46). The obtained means for this distance are shown in Table 7.

TABLE 7
LENGTH OF UPPER EXTREMITY (CM.) ON NEW YORK CITY "PRIVATE SCHOOL" CHILDREN

Age group Midpoint (yrs.)	Range	Males N	Mean	Females N	Mean	Both sexes N	Mean
3	2.5-3.4	20	39.7	19	39.8	39	39.7
4	3.5-4.4	23	42.3	25	43.1	48	42.7
5	4.5-5.4	27	46.0	26	46.3	53	46.1
6	5.5-6.4	22	49.2	26	48.7	48	48.9
7	6.5-7.4	20	52.6	20	51.5	40	52.0
8	7.5-8.4	12	54.7	13	54.1	25	54.4

Wallis found the arm component of upper limb length to increase from approximately 43 per cent at 3 years to 44 per cent at 8 years, the forearm component* to increase from 29 per cent at 3 years to 30 per cent at 8 years, and the manal component** to decrease from 28 per cent at 3 years to 26 per cent at 8 years.

*Forearm length was determined from roentgenograms as the distance "from the proximal end of the radius to . . . the point of the epiphysis corresponding to the styloid process of the adult" (p. 47).

**Distance on roentgenogram from stylion radiale "to the end of the shadow of the middle finger" (p. 47).

Talbot ('24a) obtained data for upper limb length on approximately 100 "clinically normal American children" (40 per cent males and 60 per cent females) varying in age from the beginning of the third year through the tenth year. Collection of the data took place 1915-17 on "offspring of resident normal wet nurses," Boston Infants' Hospital. The sample was considered "not to represent exceptionally well nourished or poorly nourished children," but to typify "average children within the accepted normal limits of height and weight for age" (p. 541).

Limb length was measured "from the tip of the acromion process to the end of the second finger" (p. 547). The measurements were "plotted on charts, and smoothed curves drawn to indicate the trend of growth" for each sex with age (p. 541). As published, the charts are difficult to read. The trend drawn on the chart for males is estimated to pass through 40 cm. at 3 years, 47 cm. at 5 years, 54 cm. at 7 years, and 61 cm. at 9 years. The corresponding freehand graduation of the female data is estimated to pass through 42 cm. at 3 years, 48 cm. at 5 years, 52 cm. at 7 years, and 57 cm. at 9 years. Talbot drew the conclusion that from 2 to 5 years of age upper limb length was "greater . . . in girls" and from 7 to 9 years "greater in boys" (p. 547). The paucity of data and crude method of analysis must not be overlooked.

Means based upon 300 records for length of the upper extremities obtained from physically normal children ranging in age from 2.5 to 12.5 years were reported by Grover ('15). The sample was drawn in Boston: "Most of the children were among the out-patients of the Children's Hospital, many of the older ones being relatives of the patients. Some were bed patients in the wards. Others were measured at milk stations of the Milk and Baby Hygiene Association, while a few were at the Boston Lying-In Hospital. A number also were private patients" (p. 473). "Only children with a normal appearance were measured" (p. 474). Measurement procedure was that of "placing a broad piece of splint wood well up into the axilla" and marking off the point of maximum extension of "the tip of the middle finger" (p. 476). The results are given in Table 8.

Supplementary study was made of 2 "Mongolian idiots" examined between 3 and 5 years of age, and 2 "cases of cretinism"—one examined six times between 4 and 6 years and the other eight times

TABLE 8
LENGTH OF UPPER EXTREMITY (CM.) ON BOSTON CHILDREN STUDIED ABOUT 1915

Age group Midpoint	Range (yrs.)	Males		Females		Both sexes	
		N	Mean	*N*	Mean	*N*	Mean
3	2.5- 3.4	22	34.4	15	33.5	37	34.0
4	3.5- 4.4	22	36.9	17	35.7	39	36.4
5	4.5- 5.4	11	39.3	11	39.3	22	39.3
6	5.5- 6.4	15	42.3	15	41.4	30	41.9
7	6.5- 7.4	21	45.5	17	43.9	38	44.8
8	7.5- 8.4	10	46.3	9	45.3	19	45.8
9	8.5- 9.4	15	48.2	12	47.9	27	48.1
10	9.5-10.4	17	51.7	18	51.0	35	51.3
11	10.5-11.4	12	55.7	10	52.3	22	54.2
12	11.5-12.4	14	57.2	18	57.6	32	57.4

between 6 and 14 years. While specific figures were not presented, Grover showed indirectly that all 4 subjects had limbs appreciably "shorter than normal" (p. 473).

Meredith ('46) amassed data for length of the upper extremity on 440 children in attendance at the University of Iowa Preschool Laboratories and Elementary School during the years 1937-46. The sample was formed by measuring all children enrolled in the Preschool Laboratories over the period 1937-44, and continuing to measure those of this group who later attended the Elementary School. The children available for seriatim study were remeasured at semiannual intervals. With few exceptions, each child was examined within three days of his birthday or mid-birthday age.

The subjects (230 males and 210 females) were all residents of Iowa City, Iowa, and all of the White race. They were predominantly from the professional and managerial socioeconomic groups, with a scattering (less than 10 per cent) from the commercial and skilled-trades groups. The majority of the subjects could be characterized as White children of "Old American" stock: over 90 per cent were children of northwest European ancestry.

Measurements were made of the left limb, using sliding wooden calipers. With the subject nude, the straight line distance was determined from "the most lateral point of the acromion process" to "the most distal point of the middle finger." An assistant extended the arm and forearm at the side of the body, rotated the manus so that its palmar surface faced the lateral surface of the left buttock and thigh, and extended the fingers. In application of the instrument, its

shaft was kept parallel with the long axis of the limb and care was taken to guard against any tilting of the shoulder axis. Each record was derived from measurements made independently by two anthropometrists. At a given examination, if the difference between the readings of the two anthropometrists did not exceed 0.2 cm., their mean was taken. When larger differences resulted, additional measurements were secured and the mean of not less than three readings agreeing within 0.4 cm. constituted the record.

Materials from this study are presented in Tables 9 to 12. Table 9 affords the results from statistical analysis of the total data gathered at each semiannual age from 3 to 6 years and each annual age from 6 to 10 years. Given in Tables 10 and 11 are the annual records for those individuals under study five years or longer: here the age span encompassed is 3 to 12 years. Statistics obtained from increment data for three successive biennial periods are shown in Table 12: these data were derived from columns 3, 5, 7, and 9 of Tables 10 and 11.

TABLE 9
UPPER LIMB LENGTH (CM.) ON IOWA CITY WHITE CHILDREN STUDIED 1937-46

Exact age (yrs.)	*N*	Mean	*SD*	*V*	Percentiles 10	25	75	90	Range
				Males					
3	42	40.5	1.9	4.7	38.0	39.2	41.7	42.8	36.4-45.4
3.5	67	42.2	1.9	4.5	39.5	40.9	43.4	44.3	37.7-47.5
4	58	44.1	2.0	4.5	41.5	42.8	45.4	46.7	39.8-49.3
4.5	77	45.6	2.2	4.9	42.4	44.2	47.1	48.2	40.8-50.8
5	104	47.1	2.2	4.8	43.9	45.6	48.8	49.8	41.2-52.7
5.5	92	48.5	2.3	4.8	45.5	46.8	50.1	51.7	43.9-54.0
6	92	49.9	2.3	4.6	46.7	48.4	51.6	52.9	44.9-55.6
7	64	52.8	2.7	5.1	48.6	51.0	54.6	55.7	47.0-59.0
8	54	55.7	2.7	4.9	51.6	53.9	57.5	59.1	49.2-60.8
9	43	58.2	2.8	4.7	54.5	56.7	60.2	61.7	51.1-63.1
10	37	60.5	2.9	4.8	56.2	59.2	62.8	64.2	52.8-65.8
				Females					
3	43	39.5	1.6	4.0	37.2	38.3	40.8	41.7	36.0-43.5
3.5	52	41.0	1.8	4.5	38.7	39.7	42.3	43.5	37.7-45.3
4	67	42.8	1.9	4.4	40.4	41.3	44.1	45.1	38.5-47.0
4.5	86	44.5	1.9	4.2	42.0	43.2	45.8	46.9	40.0-48.7
5	87	46.1	1.8	4.0	43.5	44.8	47.4	48.5	41.6-50.0
5.5	75	47.5	1.7	3.6	45.3	46.3	48.7	49.6	41.9-50.8
6	62	48.9	2.1	4.3	46.3	47.5	50.2	51.3	43.1-52.8
7	40	52.0	2.1	4.0	49.1	50.7	53.4	54.6	48.4-56.8
8	47	54.5	2.2	4.1	51.6	52.9	56.0	57.1	50.8-59.5
9	29	56.9	2.0	3.6	54.4	55.5	58.2	59.1	53.7-62.9
10	26	59.7	2.2	3.7	56.8	57.9	61.1	62.2	56.3-65.3

Table 9 will be seen to support the following generalizations:

1. Males exceed females in mean length of the upper extremity at all ages from 3 to 10 years. In general, the means on females are lower than those on males by 1.1 cm. For both sexes combined, the average length of the upper extremity increases from 40.0 cm. at 3 years, through 50.0 cm. shortly after 6 years, to approximately 60.0 cm. at 10 years.

2. Variability in upper limb length tends to be greater for males than for females. At every age studied, the standard deviation of the male distribution is larger than that of the female distribution. The average coefficient of variation is 4.7 per cent for males and 4.0 per cent for females. There is a fairly continuous increase in absolute variability with age. The standard deviations on males rise from 1.9 cm. at 3 years, through 2.3 cm. at 6 years, to 2.9 cm. at 10 years. The rise in the female figures is more irregular and of smaller magnitude.

3. For males, the interquartile distance increases from 2.5 cm. at 3 and 3.5 years to 3.6 cm. at 8 and 10 years. For females, there is little change in the size of the interquartile distance—the average distance is 2.6 cm. from 3 to 5 years and 2.9 cm. from 7 to 10 years. The difference in males between the 10th and 90th percentiles is 4.8 cm. at 3 years, 6.2 cm. at 6 years, and 7.2 cm. for the period 8 to 10 years. The 10th-90th distance in females averages 4.8 cm. between 3 and 5 years and 5.2 cm. between 8 and 10 years.

4. In the period 3 to 4 years the range averages 9.4 cm. for males and 7.9 cm. for females. In the period 7 to 10 years, corresponding averages are 12.1 cm. for males and 8.8 cm. for females. There is considerable overlapping of the distributions for successive ages: some children age 3 years have limbs as long as other children age 6 years.

Intercomparison of the individual protocols reproduced in Tables 10 and 11 yields findings such as follow:

1. In certain instances the same type (pattern and magnitude) of growth is found in more than one child. The upper limb lengths of Subjects 4746 and 4865 (females) are practically identical at all ages between 3 and 8 years; a like finding holds for Subjects 1124 and 6693 (males) over the age interval from 5 to 11 years. Subjects 8254 (male) and 1013 (female) have records similar at each age from 3 to 8 years, Subjects 3572 (male) and 4937 (female) similar at each age from 5 to 10 years.

TABLE 10
SERIATIM RECORDS FOR LENGTH OF UPPER EXTREMITY (CM.) ON 48 WHITE MALES

Subject	Age in years 3	4	5	6	7	8	9	10	11	12
5185	40.1	43.9	47.4	51.0	54.3	57.2				
5298	37.6	40.2	42.7	45.5	48.2	50.9				
5468	40.9	44.4	47.7	50.7	53.5	56.2				
8071	44.7	48.2	52.2	55.6	58.5	61.2				
8?54	38.3	42.0	45.1	47.8	50.2	52.1				
3014	40.2	43.3	46.8	50.6	54.0	56.2	58.1			
4748	41.0	44.3	47.9	51.3	54.7	57.4	59.9			
6134	42.3	46.4	50.0	53.4	56.5	59.3	61.7	64.0		
7291	42.9	46.0	49.3	52.5	55.6	58.4	60.9	63.0		
217		42.3	46.0	50.2	53.2	55.4	58.4			
1171		42.4	46.2	49.6	52.8	55.2	56.9			
6003		44.5	48.1	51.0	54.0	57.0	60.1			
6855		47.8	51.5	54.9	57.9	60.6	63.1			
4438		44.0	47.2	50.2	53.1	55.9	58.8	61.0	6..9	
6799		43.8	47.0	49.9	52.6	55.3	58.0	60.2	62.5	
724		43.2	45.8	48.2	50.8	53.7	56.9	59.5	61.5	63.5
1149		45.2	48.1	51.4	54.4	57.5	60.4	62.9	64.8	65.9
2187		45.4	49.0	52.2	55.3	58.5	61.6	64.2	66.2	68.2
4619		46.9	50.2	54.1	57.5	60.1	62.9	65.4	67.4	71.8
5374		42.2	45.0	47.8	50.5	53.1	56.2	59.2	61.7	64.1
3159			46.3	49.0	51.5	54.2	56.9	59.6		
4397			41.2	43.9	46.4	49.4	52.6	55.5		
4716			48.2	50.8	53.8	56.7	59.1	61.4		
6718			44.7	47.9	50.8	53.4	55.7	58.0		
130			45.8	48.7	51.6	54.2	56.9	59.3	61.3	
1124			43.4	46.3	49.4	52.1	54.5	56.4	58.2	
2817			48.8	50.7	53.2	56.0	59.1	62.7	65.3	
3572			46.8	49.9	53.1	56.0	58.9	61.7	64.7	
3630			45.9	49.6	53.0	56.1	58.8	61.0	62.6	
6693			43.3	46.6	49.1	51.9	54.3	56.2	58.1	
7056			46.7	50.1	53.8	56.6	58.7	60.6	62.4	
7393			45.6	49.0	52.6	55.4	57.4	59.4	62.2	
9586			44.3	47.5	50.4	53.3	55.8	57.9	59.5	
216			49.1	52.2	55.2	58.1	60.8	63.1	64.8	67.5
2755			45.4	49.3	52.5	55.1	57.3	59.2	60.7	62.1
3057			48.6	52.3	56.1	59.2	61.8	64.0	66.1	68.0
4277			44.7	47.6	50.6	53.4	55.9	58.3	60.4	62.0
4938			48.2	51.6	55.2	58.8	61.7	64.2	67.4	71.1
5467			49.8	52.3	55.4	58.6	62.4	65.8	68.7	70.8
9038			47.9	51.1	54.5	57.6	60.2	62.8	65.7	69.8
4933				44.3	46.9	49.2	51.1	52.8	54.1	
5166				45.9	47.9	50.2	52.8	55.4	58.0	
7095				50.9	53.9	57.0	59.9	62.5	65.2	
425				49.1	51.8	54.6	57.4	60.0	62.7	66.5
3018				50.5	53.6	56.4	59.1	61.5	63.7	65.5
4817				49.2	52.6	55.7	58.6	61.3	63.2	65.1
6883				48.8	51.5	53.9	56.3	59.0	61.5	63.7
7096				49.8	52.1	54.5	56.7	59.2	62.1	64.5

TABLE 11
SERIATIM RECORDS FOR LENGTH OF UPPER EXTREMITY (CM.) ON 36 WHITE FEMALES

Subject	Age in years 3	4	5	6	7	8	9	10	11	12
895	40.5	43.7	46.9	50.2	53.1	55.2				
2450	41.0	44.7	48.0	51.1	54.0	56.6				
4254	40.2	44.4	48.0	51.2	54.1	57.0				
4587	41.4	44.7	48.3	51.7	55.0	57.6				
4746	38.9	42.4	45.5	48.7	51.4	54.0				
4865	38.6	42.0	45.4	48.7	51.7	54.2				
8192	39.3	42.8	46.2	49.5	52.4	55.3				
3320	40.8	43.6	46.6	49.7	52.7	55.6	58.4			
9734	38.4	41.1	44.2	47.3	50.2	52.6	54.4			
1013	38.4	42.1	45.2	47.5	50.0	52.4	54.6	56.3		
1157	40.0	43.4	47.0	49.7	51.9	55.2	58.2	60.7		
2333	38.9	41.0	43.8	46.9	50.0	52.9	55.8	58.2		
4937	39.5	43.4	46.9	50.2	53.4	56.1	58.9	61.8		
1169		40.7	44.7	47.9	50.5	52.7	54.4			
424		40.3	43.1	45.9	48.7	51.3	53.8	56.7		
1673		43.9	47.1	50.2	53.3	56.3	59.1	61.2		
4224		46.4	49.6	52.6	56.1	59.4	62.9	65.3		
9356		41.4	44.9	48.5	51.8	54.6	57.3	60.0	62.7	
4879			46.8	50.0	53.1	55.9	58.7	61.1		
383			43.5	46.7	49.9	52.9	55.5	57.9	60.3	
2049			46.6	49.8	52.8	55.7	58.8	62.1	66.4	
2178			47.1	50.6	53.7	56.8	59.7	62.2	65.4	
2678			46.3	48.7	51.2	53.9	56.8	60.1	63.0	
7535			45.7	48.7	51.3	53.5	55.7	58.2	60.6	
2318			46.5	49.5	52.7	55.5	58.1	60.5	63.0	66.6
4749			44.9	48.0	51.0	53.7	56.4	59.4	62.7	67.4
5413			45.9	49.2	52.5	55.3	57.8	60.6	64.0	67.8
6207			46.4	48.6	51.0	53.8	56.6	58.9	60.9	62.6
753				47.1	49.2	51.7	54.8	58.0	60.7	
4158				46.0	48.9	51.4	53.7	56.8	61.1	
4398				46.7	49.5	52.3	54.9	57.3	59.6	
211				48.0	50.6	53.2	55.8	58.4	61.3	65.3
393				47.2	50.2	52.9	55.5	57.6	60.4	64.0
472				52.2	55.3	58.1	61.1	63.8	67.2	70.5
2147				49.5	52.7	55.6	57.9	60.0	62.1	65.1
7732				48.1	51.0	53.7	55.9	57.9	59.8	62.5

2. Series of values which diverge markedly with age are obtained on Subjects 217 and 8254 (males), Subjects 5413 and 7535 (females), and Subjects 1149 and 4938 (males). Compared with the upper limb length of Subject 8254, that of Subject 217 is longer by 0.3 cm. at 4 years, 2.4 cm. at 6 years, and 3.3 cm. at 8 years. The records on Subject 5413 exceed those on Subject 7535 by 0.2 cm. at 5 years, 1.8 cm. at 8 years, and 3.4 cm. at 11 years. Subjects 1149 and 4938 have records approximately alike at 5 and 6 years, differing by 1.3 cm. at 8 and 9 years, and differing by 5.2 cm. at 12 years.

3. Pairs of upper limb length trends which converge with age include those of Subjects 383 and 6207 (females) and Subjects 3572 and 216 (males). The distance between the trend lines for the former two subjects narrows from 2.9 cm. at 5 years to 0.6 cm at 11 years. For the latter two subjects, the difference in limb length is less at 11 years than at 5 years by 2.2 cm.

4. Subjects 2678 and 2318 (females) have similar records at 5 years, records which differ by 1.6 cm. at 8 years, and similar records again at 11 years. The same relation obtains for the records of Subjects 3630 and 7096 (males): there is divergence from a difference of 0.2 cm. at 6 years to a difference of 2.1 cm. at 9 years, followed by convergence to a difference of 0.5 cm. at 11 years.

5. Over the period 4 to 8 years, gains of 11.5 cm. are registered for Subjects 6799 (male), 895 (female), and 9734 (female), and gains of 12.9 cm. for Subjects 3014 (male), 6134 (male), and 4587 (female). The greatest differences in gain over these years are 10.1 cm. and 13.3 cm. on males (Subjects 5185 and 8254), 10.3 cm. and 13.2 cm. on females (Subjects 1013 and 9356).

6. For the period 8 to 12 years, the percentage gains made by male Subjects 2755 and 425 are 12.7 and 21.8, respectively. Corresponding minimum and maximum increments on females are 16.4 per cent (Subject 6207) and 25.5 per cent (Subject 4749). Identical percentage gains over the age span 8 to 12 are found for female Subjects 6207 and 7732 (16.4 per cent)and for male Subjects 4277 and 3018 (16.1 per cent).

TABLE 12

BIENNIAL INCREMENTS IN UPPER LIMB LENGTH FOR IOWA CITY WHITE CHILDREN OF MIDDLE AND UPPER CLASSES

Biennial period (yrs.)	Males		Females		Both sexes					
	N	Mean	*N*	Mean	Minimum	10	25	75	90	Maximum
					Centimeter increase					
4- 6	20	6.6	18	6.4	5.0	5.6	6.2	7.0	7.2	7.9
6- 8	48	5.7	36	5.6	4.3	5.0	5.4	6.0	6.3	7.2
8-10	37	5.1	26	5.3	3.6	4.3	4.7	5.5	6.1	7.2
					Percentage gain					
4- 6	20	14.8	18	15.0	11.6	13.3	14.0	15.7	17.0	18.7
6- 8	48	11.5	36	11.5	9.0	10.3	10.9	12.1	12.8	14.0
8-10	37	9.2	26	9.6	7.1	7.9	8.6	10.0	11.5	12.3

Lastly findings which may be drawn from Table 12 are:

1. There is a continuously declining rate of growth in length of the upper extremities during the age period 4 to 10 years. To illustrate: Gains exceeding 11.5 per cent are obtained on the entire sample for the interval 4 to 6 years, on 50 per cent of the sample for the interval 6 to 8 years, and on less than 10 per cent of the sample for the interval 8 to 10 years.

2. The increments are similar on both sexes. Over the biennium 6 to 8 years, males and females yield means that are identical in percentage gain and practically alike in centimeter increase. There is the suggestion of slightly less variability among females: in each instance the minimum and maximum increments are male values.

3. For both sexes jointly, the mean augmentation in length of the upper extremity decreases from approximately 3.3 cm. per annum in the fifth year to 2.5 cm. per annum in the tenth year. Dispersion of individual annual increments about each mean shows roughly 10 per cent to fall between 0.9 and 0.4 cm. below, 15 per cent between 0.4 and 0.2 cm. below, 50 per cent between 0.2 cm. below and 0.2 cm. above, 15 per cent 0.2 to 0.4 cm. above, and 10 per cent 0.4 to 0.9 above.

Trend lines for upper limb length—some drawn to averages and some depicting the growth of individuals—were published by Davenport ('44). The individual data were for 10 males and 10 females between the ages of 6 and 18 years, the mass data for "high-grade feebleminded" children 8 to 17 years of age and children of "presumably normal" intelligence 2.5 to 17 years of age. Three separate samples comprised the presumably normal group. For the age period 2.5 to 3 years, there were 19 males and 15 females examined at "four-week intervals" at the Columbia University Child Development Clinic, Babies Hospital, New York City. For the age period 3 to 6 years, "24 boys and 30 girls of a children's home were measured from one to three times each" (p. 377). Both these samples were composed of "entirely normal children, 95 per cent of North European extraction" (p. 377). The third normal sample encompassed the age period 6 to 18 years. Here, the subjects—78 males and 64 females "from the Orphan Society of Brooklyn"—were "United States born" and "attended public grammar and high schools." They were "well and uniformly fed and cared for. Practically all were of English and

Scotch ancestry. . . . Some were measured only once, but most of them five times" (p. 377).

The high-grade feebleminded group consisted of "over 60" children of each sex in residence at the Letchworth Village Development, New York. This group was described as approximately 50 per cent "old United States stock and Nordic," 30 per cent "Italian" and 20 per cent "Jewish" (p. 377). Many were measured at several ages.

Upper limb length was determined in several different ways: (1) by measuring the height from the floor (subject standing erect) of acromiale and of dactylion III, then subtracting the smaller figure from the larger; (2) by measuring the height from the floor of acromiale and of stylion, subtracting, and then adding the length of the hand as obtained from a tracing; and (3) by measuring directly from acromiale distally. Comparability of results was checked by securing measurements on the same individual by more than one of these techniques: "Thus, with the subject standing erect, arms hanging straight down, the distance of the landmarks from the floor was measured vertically. . . . Immediately thereafter the segments of the upper limb were measured directly . . . " (p. 426).

Presentation of quantitative results on the "high-grade feebleminded" and "normal intelligence" groups was restricted to a single graph affording central tendency curves for each sex—a small graph carrying a fairly crude centimeter scale. Values at annual ages, as read from this graph, are given in Table 13. For the normal group, Davenport concluded: "The upper limb from 3 to 12 years increases about 2.5 cm. p.a." (p. 379). There is a spurt at adolescence (which occurs earlier in girls than boys) and in connection with this spurt "the mean limb of girls comes, at 13 years of age, to exceed that of boys to the amount of 15 mm."; by 15 years of age boys again exceed girls in mean length of the upper limb (p. 379). Other statements with reference to central tendency were: "Negro children have upper limbs 2 to 6 cm. longer than whites or about 8 to 10 per cent" (p. 438); the upper limb length of Mongloid dwarfs 16 years of age is 11 cm. less than that for the "presumably normal" or "standard" White series (p. 444); upper limb length increases "with general mental and physical development, in the order Mongloid, idiot, feebleminded, standard" (p. 458).

Turning to the 20 limb length curves for individuals, Table 14 affords

TABLE 13
CENTRAL TENDENCY ESTIMATES FOR LENGTH OF UPPER EXTREMITY (C.M.) ON WHITE INFANTS REPRESENTING TWO INTELLECTUAL LEVELS

Age (yrs.)	*"Presumably normal" group* Males	Females	*"High-grade feebleminded" group* Males	Females
3	40.5	39.5		
4	43.0	42.0		
5	45.5	44.5		
6	48.0	47.0	46.5	
7	50.5	50.0	49.0	47.5
8	52.5	52.5	51.5	52.0
9	55.5	54.5	53.0	55.5
10	58.0	57.5	55.5	58.0
11	59.5	60.5	58.5	60.5
12	62.0	63.5	61.5	62.5
13	64.5	66.0	63.5	63.5
14	67.0	67.0	66.5	66.0
15	70.5	67.5	70.0	68.0
16	74.0	69.0	72.5	68.5
17	78.0	73.0	73.5	68.0

TABLE 14
RECORDS (READ FROM GRAPHS) FOR UPPER LIMB LENGTH (CM.) IN TWENTY INDIVIDUALS

Subject	Age in years 6	8	10	12	14	16	18
		Males					
Acromegalic,[1] Italian			67.0	70.5	73.5	80.0	
Feebleminded, Negro				67.5	71.0	81.5	
Feebleminded, Nordic		53.0	60.0	64.0	69.0	73.5	80.0
Feebleminded, Nordic		51.5	56.5	62.0	66.0	69.5	
Feebleminded, Italian		49.5	55.0	59.5	63.5	65.5	70.0
Feebleminded, Nordic		49.0	54.0	58.5			
Feebleminded, Nordic			52.5	59.0	62.5	67.5	72.0
Microcephalic, Italian				56.5	59.5	65.0	70.0
Cretin, Korean-White[2]	43.0						
Mongoloid dwarf[3]				54.0	58.0	63.0	68.5
		Females					
Dizygotic twin, Negro						81.0	
Dizygotic twin, Negro[4]						73.5	
Monozygotic twin, Nordic			58.0	64.0	67.5	68.0	
Monozygotic twin, Nordic[4]			57.5	63.5	67.0	68.5	
Cretin, treated[5]					59.5	62.0	64.0
Ateliotic,[6] Nordic				50.5	55.0	60.0	63.0
Ateliotic,[6] Nordic				50.5	53.5	59.0	
Cretin, Nordic		45.0	47.0				
Ateliotic,[6] Jewish				48.5	52.0	55.0	56.0
Chondrodystrophic dwarf[7]						51.0	51.0

[1]"Hyperpituitary condition" p. 445.
[2]"He is stated to have had a Korean father and White mother" p. 442.
[3]Provisionally defined as "a child who did not receive the essential developmental impulses (hormonal catalysts) during fetal life, and is not provided with an endocrine mechanism for making good entirely these deficiencies in later life" p. 443.
[4]Sister of the preceding subject.
[5]Received thyroid extract intermittently.
[6]"So-called ateliotic, infantile, and microsomic dwarfs" p. 441.
[7]"A condition of dwarfness that is due to malformation of the limbs ascribed to retarded or abnormal development of the cartilage-precursor of the long bones" p. 442.

values read from these. Each subject is identified for sex and other distinguishing characteristics. One of the major findings which Davenport considered his individual records to register was that of abnormally short upper extremities in dwarfs—chondrodystrophic, Mongoloid, microcephalic, cretinous, and ateliotic.

Between "the spring of 1927 and . . . the fall of 1929," Palmer ('44) accumulated 944 records for length of the left upper extremity on "normal . . . Caucasian" children 2.5 to 17.5 years of age. Most of the subjects under 6 years of age were obtained through the "nursery school and kindergarten divisions" of the Institute of Child Welfare, University of Minnesota, and were "from the upper socioeconomic classes" (pp. 120-123). At ages above 6 years, the subjects were practically all orphanage residents ("The City of Childhood, Mooseheart, Illinois") drawn "from the lower economic strata" (pp. 121, 123).

Limb length was "determined indirectly": First, "the linear distance from the plantar surface to the tip of the third digit of the left hand, the medio-plantar distance, was measured"; secondly, "this value was subtracted from shoulder height (the standard acromion-planta length)" (p. 119). The resultant measures will be recognized to represent the straight line distance from acromiale to dactylion III, with the limb paralleling the lateral thoracic wall.

Table 15 gives the values obtained from statistical reduction of Palmer's data. With particular reference to central tendency:

1. The means at corresponding ages from males and females are generally similar over the preschool and elementary school years, but markedly different in late adolescence. On each sex the mean at 13 years is greater than that at 3 years by 27.2 cm., or almost 70 per cent; in contrast, means at age 17 exceed those at age 13 by 10.1 cm. or 15 per cent on males, and by 4.4 cm. or less than 7 per cent on females.

2. There is no indication that the portion of the sample representing an "above average" socioeconomic level differs from the portion representing orphanage children; *i.e.*, the means beginning at age 6 years are continuous with those for younger ages. Explicitly, the central tendency curve drawn to means for both sexes combined rises 5.9 cm. between 4 and 6 years, and 5.7 cm. beween 6 and 8 years. The rise on orphanage children of 5.7 cm. between 6 and 8

TABLE 15
UPPER LIMB LENGTH (CM.) ON PHYSICALLY NORMAL WHITE CHILDREN STUDIED 1927-29

Age group Midpoint (yrs.)	Range	N	Mean	SD	Percentiles 10	25	75	90
			Males					
3	2.5- 3.4	10	39.1		37.1	37.9	40.6	41.7
4	3.5- 4.4	25	42.6	2.4	39.7	41.3	44.0	45.5
5	4.5- 5.4	30	45.5	2.4	42.3	44.1	46.8	48.8
6	5.5- 6.4	28	48.2	2.4	44.2	46.9	49.8	51.2
7	6.5- 7.4	22	50.8	2.2	47.2	49.5	52.4	53.8
8	7.5- 8.4	36	54.2	2.8	50.2	52.5	56.2	57.8
9	8.5- 9.4	35	56.5	2.8	52.8	54.7	59.0	60.7
10	9.5-10.4	30	58.4	3.2	54.3	56.3	60.8	62.7
11	10.5-11.4	46	60.8	3.4	56.2	58.8	63.3	65.4
12	11.5-12.4	53	63.7	3.0	59.1	61.6	65.7	67.6
13	12.5-13.4	55	66.3	4.0	61.4	64.2	69.0	71.0
14	13.5-14.4	34	69.0	3.3	64.2	66.4	71.8	73.4
15	14.5-15.4	24	72.8	4.4	66.4	69.3	75.0	77.2
16	15.5-16.4	31	75.6	3.4	70.7	73.0	78.3	80.0
17	16.5-17.4	21	76.4	3.7	72.9	74.6	79.5	81.2
			Females					
3	2.5- 3.4	19	39.2		36.4	37.2	40.8	42.8
4	3.5- 4.4	31	42.5	2.3	39.6	40.8	44.1	45.2
5	4.5- 5.4	21	45.5	2.1	42.8	43.8	46.8	48.1
6	5.5- 6.4	15	48.7	1.9	45.7	47.0	50.1	52.8
7	6.5- 7.4	25	50.8	2.7	47.4	49.0	52.9	54.1
8	7.5- 8.4	24	54.0	2.8	50.3	51.7	55.9	57.2
9	8.5- 9.4	26	55.8	2.7	52.4	53.6	58.2	59.3
10	9.5-10.4	41	58.6	2.6	54.7	56.0	60.8	62.2
11	10.5-11.4	39	61.2	3.6	56.3	58.4	64.0	65.5
12	11.5-12.4	39	63.8	3.6	58.9	61.3	66.6	67.7
13	12.5-13.4	43	66.4	3.7	61.6	63.9	68.8	70.7
14	13.5-14.4	52	68.5	3.8	64.1	66.1	70.8	72.9
15	14.5-15.4	48	69.4	2.9	65.0	67.2	72.1	73.8
16	15.5-16.4	30	70.3	3.5	65.9	67.8	73.1	75.3
17	16.5-17.4	11	70.8		66.1	68.0	74.2	76.0

years will be found to coincide with the rise over the same period obtained by Meredith ('46) on children drawn mainly from the professional and managerial classes.

3. Compared with the means secured by Meredith for children 3 to 10 years of age, the corresponding means from Palmer's study are appreciably smaller. Taking both sexes together, the Meredith data collected 1937-46 yields means higher than those from the Palmer data collected 1927-29 by approximately 1.0 cm. over the period 3 to 6 years and 1.4 cm. over the period 7 to 10 years. While the possibility that the two studies differ systematically in limb orientation or landmark location cannot be rejected, the suggestion is no less plausi-

ble that between the late 1920's and early 1940's there was some secular increase in length of the upper extremities.*

Simmons ('44) analyzed 6,200 measurements of upper limb length collected 1931-42 on approximately 800 children at ages between 2.5 and 17 years. Children were enrolled in the study at all ages from 2.5 to 14 years upon parental "agreement to continued participation" (p. 1). Examinations were made at semiannual intervals below 5 years of age, and at annual intervals thereafter. Some subjects were examined as many as fourteen times, others no more than twice: the average number of records per child was slightly less than eight. As a whole, the subjects constituted "a selected sampling of the Greater Cleveland child population": All were White and "free from gross physical and mental defects"; the majority of their parents were "above-average both economically and educationally" and "of North European ancestry" (p. 1).

Measurements were made by means of an "anthropometer of Martin design" with the subject "dressed in indoor clothing" (p. 12). "The subject stood with both upper extremities extended forward, the palms of the hands directed medially. The length of the left upper extremity was made from the inferior surface of the tip of the acromion to the tip of the middle finger" (p. 14). All examinations were scheduled "at or near" the selected annual and semiannual ages, and usually the measurements were obtained by Dr. C. C. Francis or Miss R. Locher.

The results are shown in Table 16. Comparing the means from the two sexes, those on males are the higher over the age period 2.5 to 10 years, those on females at 12 and 13 years, and those on males from 14 to 17 years. Extending comparison to include magnitude as well as direction of sex differences, the female means are smaller by 0.9 cm. at 3 to 4 years, smaller by 0.6 cm. from 5 to 8 years, larger by 0.6 cm. at 12 to 13 years, and smaller by upwards of 4.0 cm. after 15 years. There is considerable overlapping of the distributions for successive ages, *e.g.*, some children age 2.5 years have upper limbs as long as other children age 5 years; similarly upper limbs of the same length are recorded for individuals differing in age from 7 years to 13 years.

*Secular increase in the stature of children over recent decades is well established. See, for instance, Meredith and Meredith ('44).

TABLE 16
LENGTH OF UPPER EXTREMITY (CM.) ON SELECTED OHIO CHILDREN STUDIED 1931-42

Age (yrs.)	*Males*				*Females*			
	N	Mean	*SD*	Range	*N*	Mean	*SD*	Range
2.5	124	36.9	1.7	33.2-41.3	125	35.9	1.9	30.1-40.4
3	177	38.9	1.7	35.5-43.4	171	37.9	1.9	34.0-43.0
3.5	187	40.4	1.8	36.4-45.6	187	39.6	2.0	33.4-44.5
4	207	42.3	1.9	38.1-47.6	220	41.4	1.9	37.0-45.5
4.5	201	43.8	2.0	39.7-48.9	215	43.2	2.2	37.9-49.7
5	222	45.3	2.1	40.2-50.9	228	44.8	2.2	39.0-51.8
6	215	48.6	2.3	43.9-50.0	240	48.0	2.6	42.3-51.5
7	209	51.6	2.3	46.6-58.1	223	50.9	2.7	44.3-59.6
8	200	54.3	2.4	48.5-60.4	212	53.7	2.7	49.8-62.2
9	171	56.7	2.6	51.2-67.4	191	56.3	2.8	49.5-64.7
10	170	59.3	2.7	51.8-67.4	182	59.0	3.0	52.7-68.8
11	178	61.8	3.1	54.7-71.9	201	61.9	3.1	54.5-71.3
12	201	64.2	3.5	55.0-73.5	192	64.9	3.1	56.4-73.0
13	184	66.8	3.9	56.5-80.2	170	67.3	3.0	56.7-73.9
14	164	70.5	4.1	59.8-82.7	143	69.1	2.8	63.9-76.6
15	128	73.5	3.7	62.8-81.8	111	69.5	3.0	63.0-76.2
16	98	74.9	3.3	66.0-82.0	70	70.4	3.1	63.2-79.5
17	60	75.7	3.4	68.1-87.6	28	69.7	2.9	62.5-74.9

Simmons reported findings pertaining to changes with age in the linear weightings of the three gross components of the upper extremity. In general, the contributions made to limb length increased in the case of arm length remained fairly constant in the case of forearm length and decreased in the case of hand length. To illustrate. Mean length of arm (acromiale to radiale, upper extremity "extended forward") constituted 40.1 per cent of mean length of the upper extremity at 6 years and increased to 41.4 per cent at 17 years. The percentages at corresponding ages approximated 33.2 and 33.1 for forearm length ("from proximal to distal ends of radius") and declined from 26.7 to 25.5 for length of manus ("from distal end of styloid process of left radius to tip of middle finger").

For each of two ethnic groups, Matheny and Meredith ('40) studied upper limb length at consecutive annual ages from 6 to 17 years. The subjects were males, 1,100 of Finnish ancestry and 880 of Italian ancestry. Both samples were drawn in the vicinity of Hibbing, Minnesota.* The data were collected simultaneously on both samples (1938-39) and all measurements were made by the same anthropometrist (Matheny). Annual family income was $1,500 or lower" for 84 per cent of each group, and "over $2,000" for less than

*From some 30 communities within a radius of 50 miles of Hibbing.

4 per cent of each group. Both groups gave similar distributions for occupation of father—distributions composed largely (around 85 per cent) of unskilled and semiskilled workmen.

Length of the left upper extremity was determined with wooden sliding calipers (subject nude) as the distance from "the most lateral point of the acromion process" to "the most distal point of the middle finger." The limb was extended at the side of the body and the manus rotated so that its palmar surface faced the lateral surface of the thigh. In applying the measuring instrument the shaft was kept parallel with the long axis of the limb and care was taken to guard against any tilting of the shoulder axis. Always the value recorded represented the average of two or more separate determinations.

Table 17 presents statistics obtained from twelve age subdivisions of the data on each ethnic group. Selected findings are:

TABLE 17

UPPER LIMB LENGTH (CM.) ON MINNESOTA MALES OF ITALIAN AND FINNISH ANCESTRY

Age group Midpoint (yrs.)	Range	*N*	Mean	*SD*	*V*	Percentiles 25	75	Range
		Males of Italian descent						
6	5.5- 6.4	40	48.1	2.1	4.4	46.3	49.6	45.2-52.6
7	6.5- 7.4	50	50.9	2.4	4.7	49.2	52.5	46.2-55.8
8	7.5- 8.4	51	53.6	2.3	4.3	52.0	55.0	49.7-59.4
9	8.5- 9.4	59	55.6	2.4	4.3	54.2	57.1	49.6-60.6
10	9.5-10.4	69	58.2	2.3	3.9	56.7	59.6	53.4-64.4
11	10.5-11.4	79	60.5	2.2	3.6	59.0	62.1	54.7-66.9
12	11.5-12.4	80	63.3	2.5	4.0	61.4	65.1	56.3-69.4
13	12.5-13.4	80	65.3	3.6	5.6	63.0	67.5	57.4-73.9
14	13.5-14.4	90	68.9	4.3	6.2	66.0	71.5	59.2-78.9
15	14.5-15.4	93	71.0	3.8	5.4	68.5	73.6	63.3-78.9
16	15.5-16.4	93	73.8	3.7	5.1	71.4	76.3	64.4-82.2
17	16.5-17.4	100	75.7	2.9	3.8	73.5	77.7	69.2-82.8
		Males of Finnish lineage						
6	5.5- 6.4	52	48.9	2.3	4.7	47.3	50.5	44.1-53.4
7	6.5- 7.4	83	51.8	2.6	5.0	49.8	53.8	47.2-57.9
8	7.5- 8.4	92	54.5	2.7	5.0	52.5	56.5	49.0-61.7
9	8.5- 9.4	93	56.6	2.7	4.8	54.4	58.8	50.1-62.7
10	9.5-10.4	92	59.4	3.0	5.1	57.4	61.5	50.5-66.9
11	10.5-11.4	100	61.6	2.9	4.8	59.6	63.6	54.8-68.9
12	11.5-12.4	98	64.3	2.9	4.5	62.3	66.3	57.2-70.3
13	12.5-13.4	102	66.4	3.4	5.2	64.1	68.6	59.4-74.8
14	13.5-14.4	93	69.9	3.8	5.4	67.6	72.2	61.0-77.8
15	14.5-15.4	100	72.3	4.3	5.9	69.6	74.8	60.9-82.4
16	15.5-16.4	101	75.2	3.3	4.4	73.1	77.8	68.2-82.3
17	16.5-17.4	96	76.7	3.5	4.5	74.3	79.4	69.2-86.9

1. At all ages from 6 to 17 years, mean length of the upper extremity is greater for the males of Finnish ancestry than for those of Italian ancestry. The magnitude of the difference approximates 1.0 cm. over the age interval 6 to 9 years and 1.2 cm. over the age interval 14 to 17 years.

2. Three-fourths of the Finnish group representing age 7 years have limb lengths exceeding the mean of the Italian group representing age 8 years. Similarly in subsequent comparisons, the 75th percentile at a selected age for schoolboys of Finnish descent exceeds the mean at the next older age for schoolboys of Italian descent.

3. In general, during childhood the sample with Finnish ancestry is the more variable, in adolescence the two ethnic samples are equally variable. Over the period 6 to 12 years, the standard deviations average 2.3 cm. on the offspring of Italians and 2.7 cm. on the offspring of Finns; averages from the coefficients of variation are 4.2 per cent and 4.8 per cent respectively. Over the period 13 to 17 years the standard deviation averages from both ethnic groups are 3.7 cm., the coefficient of variation averages 5.2 per cent and 5.1 per cent.

4. Meredith's means covering the age span 6 to 10 years (males of northwest European ancestry representing an "above average" socioeconomic level) are higher than those from this study by 2.1 cm. in the case of males of Italian lineage and by 1.2 cm. in case of males of Finnish lineage. The male means from Palmer (orphanage inmates studied 1927-29) are similar to those for the males of Italian lineage at ages 6 to 7 years and of Finnish lineage at ages 16 to 17 years.

In the three remaining studies—each made on male subjects within the age limits of 9 and 18 years—separate data are furnished covering the distances (a) "shoulder to elbow" and (b) elbow to finger tip. For all three, summation of the two segmental lengths involves duplicate use of part of the elbow region and consequently does not yield a morphologically valid figure for length of the upper extremity. Notwithstanding the studies do afford, both individually and collectively, some valuable findings. Hall ('96a) reported medians at annual ages from 9.5 to 17.5 years derived from measurement of 1,700 schoolboys considered "homogeneous as to race, nationality, sex, social condition and physical development" (p. 27). The subjects were in attendance between 1889 and 1893 at three private schools in or near Philadelphia—"the William Penn Charter School, the

Haverford Grammar School, and the Wilmington Friends' School" (p. 21). "Their parents were almost without exception born in America, and the families came originally from England. The families were with very few exceptions well-to-do" (p. 21). The "exceptional opportunities" which all three institutions offered for physical development "induced a great majority of the students and pupils to enter actively into athletics" (p. 21).

Measurements were made "upon the nude body" using wooden calipers. The arm was oriented parallel with the lateral thoracic wall and the remainder of the limb positioned at right angles. Distances were obtained (a) "between the upper surface of the acromion process and the lower surface of the olecranon" and (b) "from the superior end of the olecranon to the tip of the third digit" (pp. 24-25). Data collection was stated to have been carried out "under the most favorable circumstances" and with great care.

LENGTH OF UPPER EXTREMITY (CM.) ON PRIVATE SCHOOL MALES MEASURED AROUND 1890

	Age group midpoints (yrs.)								
	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5
Number	93	122	132	143	203	209	233	284	290
Median	61.1	64.5	66.5	68.6	72.8	75.6	79.6	81.9	83.2

The average yearly rise in the median trend is 2.7 cm. over the period 9.5 to 11.5 years, 3.3 cm. over the period 11.5 to 15.5 years, and 1.3 cm. over the period 16.5 to 17.5 years. Interpolated central tendency values approximate 62.7 cm. at 10 years and 82.7 cm. at 17 years, the value for 17 years exceeding that for 10 years by 20.0 cm. Increases in central tendency between 10 and 17 years from other male samples are 20.0 cm. (Davenport's "presumably normal" series), 18.0 cm. (Davenport's "high-grade feebleminded" and Palmer's orphanage series), 17.5 cm. (Meredith's "Italian" series), 17.3 cm. (Meredith's "Finnish" series), and 16.4 cm. (Simmons' "above-average . . . North European" series).

Percentiles describing distributions for measures of the upper limb at six consecutive ages from 11.5 to 16.5 years were published by Moon ('96). The basic data were accumulated over an eight-year period from annual measurement of "each boy of the McDonogh School situated near Baltimore, Md." (p. 3). Description of the sample with reference to ethnic composition and socioeconomic repre-

sentation was lacking, as also was specific designation of the anthropometric procedures employed. Regarding the latter, since (a) Moon's tables afford figures for the two segmental "lengths" of each upper limb, "Shoulder-Elbow" and "Elbow-Tip"; and (b) the text of the publication is focused upon "comparison" of the findings on McDonogh School boys with those on "Yale University students" from Seaver, it appears highly probable that the measurement technique was that used by Seaver ('09). To wit: After "placing the forearm against the chest in a horizontal position," with the elbow region positioned slightly medial to the most lateral projection of the chest wall, (a) the "length of the arm from shoulder to elbow" was obtained "with the fixed branch of the caliper resting on the acromion process and the sliding branch against the olecranon process," and (b) the length of the forearm and hand from the back of elbow to terminal point of the longest digit "by placing the fixed branch of the caliper against the olecranon tip" and bringing the sliding branch "against the tip of the middle finger" (p. 37).

Included in Moon's tables are nineteen percentile values characterizing the distribution for each age, limb, and dimension. Specific for year of age and right or left extremity, the 50th percentiles from the two segmental distances were added. The resulting composite medians are presented in the following tabulation:

UPPER LIMB LENGTH (CM.) ON MALES AT THE MCDONOGH SCHOOL, MARYLAND, ABOUT 1890

	Age group midpoints (yrs.)					
	11.5	12.5	13.5	14.5	15.5	16.5
Number of subjects	100	120	115	150	150	130
Median: Right limb	64.9	68.1	69.6	72.5	76.3	79.2
Left limb	64.6	67.6	69.1	72.2	76.1	78.7

Findings are:

1. There is a consistent tendency for the right upper extremity to be slightly longer than the left. The magnitude of the difference approximates 0.4 cm. It will be recalled that for the age period from 3 to 6 years a difference similar in direction, although smaller in magnitude, was obtained in a study reported from the Iowa Child Welfare Research Station ('29).

2. Compared with the medians from the preceding study by Hall, Moon's medians at corresponding ages are considerably lower through-

out. The factors responsible for this lack of similarity are not clearly identifiable. It is not apparent, for instance, why the two series of medians should differ by less than 2.0 cm. at 11.5 and 12.5 years and by more than 3.0 cm. at 14.5 and 15.5 years. From the standpoint of variation in anthropometric technique, the results tend not to accord with expectation. Considering the designated discrepancy between Hall and Seaver in arm orientation—also the possibility of an appreciable systematic difference in placement of the calipers on the acromion process—any marked divergence in the findings from the two studies would be anticipated to lie primarily with the arm component. Actually, the two studies are somewhat more alike for arm length (average difference over the period 13.5 to 16.5 years approximates 1.4 cm.) than for forearm and hand length (average difference 13.5 to 16.5 years 1.8 cm.).

The investigations of Hall and Moon antedate by upwards of two decades other North American investigations on children of elementary and high school age. Consequently, they are uniquely valuable with reference to the problem of secular variation. In order to take advantage of this value, Meredith ('47) collected data for comparison representing the two ages 12.5 years and 14.5 years. The subjects were White males in attendance 1945-47 at the University of Iowa experimental high school. They were largely of northwest European ancestry and from families in the professional and managerial occupational groups. Measurements were made on the left limb, following the procedure employed by Hall. The median typifying age 12.5 years (derived from measurement of 35 subjects between the ages of 12 and 13 years) exceeded that of Hall by 7.2 cm. and that of Moon by 8.2 cm. Alignment at age 14.5 years showed the medians of Hall and Moon to be lower than the Meredith median (52 subjects age 14 to 15 years) by 6.8 cm. and 10.2 cm. respectively. Practically identical medians were obtained at 12.5 years by Meredith (75.8 cm.) and at 14.5 years by Hall (75.6 cm.). With differences of this magnitude, some degree of secular increase must be regarded as an established biologic fact. After generous allowance has been made for systematic and chance variables possibly operative in sample selection and data collection, it appears a tenable inference that the length of the upper extremity (*i.e.*, the straight line distance from acromiale to dactylion III) in 14-year-old North American White males is no

less than 4.0 cm. longer today than was the case half a century ago.

As with earlier sections of this paper, the present section on "Childhood and Adolescence" was projected to furnish both a systematic review and a working synthesis. Thus far, the currently accessible investigations pertaining to upper extremity length in North American children between the ages of 3 and 17 years have been ordered and displayed. An overall integration of these investigations follows:

1. Cognizance must first be taken of the fact that the aggregate knowledge obtainable from the fourteen studies would have been far greater had the anthropometric technique been the same in each instance. Limb orientation included extension "straight forward at shoulder level" (Simmons, Wallis '31a), forearm and hand segments at right angles to arm segment (Iowa Child Welfare Research Station, Hall '96a), and extension of entire limb in line with the long axis of the body (Davenport, Palmer, Meredith '46). Proximal landmarks ranged from "upper surface of the acromion process" (Hall '96a) through "inferior surface of the tip of the acromion" (Simmons) to "crease in the arm pit" (Grover): distal landmarks were "end of the second finger" (Talbot '24a) and end of the middle finger. Two investigators (Crum and Moon) omitted any designation of their measurement methods. Future investigators of upper limb length should endeavor not to add further to the substantial scientific losses which poorly specified and unstandardized procedures have entailed.

2. Composite averages descriptive of nonpathologic White children were obtained for upper limb length defined as the distance from acromiale to dactylion III with the limb extended at the side of the body. The major source materials employed were those of Davenport, Palmer, and Meredith ('46). Other studies useful for their indication of the form of the central tendency curve during the adolescent years were those of Simmons, Matheny and Meredith, and Hall ('96a). Over the age period from 3 to 13 years, figures were sought for both sexes combined; at ages 14 to 17 years each sex was considered separately. The results are incorporated in Figure 1. It will be seen that average length of the superior extremity on North American White children (children largely of northwest European descent examined during the secular period 1925-45) approximates 43.0 cm. (16.9 inches) at 4 years, 48.5 cm. (19.1 inches) at 6 years, 53.8 cm. (21.2 inches) at 8 years, 58.9 cm. (23.2 inches)

at 10 years, and 64.4 cm. (25.4 inches) at 12 years. At 15 and 17 years the averages for females are 70.0 cm. (27.6 inches) and 70.8 cm. (27.9 inches) respectively. The averages for males at these ages are 73.3 cm. (28.9 inches) and 77.0 cm. (30.3 inches).*

3. At all ages prior to 14 years sex differences in average length of the upper extremity are less than one-half inch: during the period from 3 to 10 years males have longer limbs than females by about 0.9 cm., at 11 years the two sexes are practically alike, between 12 and 13 years males have shorter limbs than females by roughly 0.6 cm., and around 13.5 years the two sexes again are alike. Over the high school years the average superior limb length of males comes to exceed that of females by upwards of two inches. Specifically, the female limb is shorter than the male limb at consecutive annual ages from 14 to 17 years by about 1.1 cm., 3.3 cm., 5.1 cm., and 6.2 cm. respectively. In arriving at this series of generalizations, combined use was made of the obtained differences between male and female averages from Crum, Davenport, Grover, Iowa Child Welfare Research Station, Meredith ('46), Palmer, Talbot ('24a), Simmons, and Wallis ('31a).

4. During childhood and early adolescence there is an increase in the absolute variability of upper limb length (Simmons, Matheny and Meredith, Meredith '46, Palmer). For physically normal North American White children of each sex, approximate dispersion values in childhood are: Interquartile distance, 2.8 cm. at 4 years, 3.2 cm. at 6 years, 3.5 cm. at 8 years, and 3.8 cm. at 10 years; distance between 10th and 90th percentiles, 5.3 cm. at 4 years, 6.1 cm. at 6 years, 6.8 cm. at 8 years, and 7.4 cm. at 10 years; and range (distance between extreme values), 9.5 cm. at 4 years, 11.0 cm. at 6 years, 13.0 cm. at 8 years, and 15.5 cm. at 10 years. Transposing to inches and casting in a form more convenient for normative use, at age 4 upper limb lengths are distributed about 10 per cent between 1.9 and 1.0 inches below the average, 15 per cent between 1.0 and 0.6 inches below, 50 per cent between 0.6 inches below and 0.6 inches above, 15

*Over the period from birth to 17 years, the increases in central tendency are 48.8 cm. (19.2 inches) for females, and 54.6 cm. (21.5 inches) for males. These increases represent gains on birth status of 222 and 244 per cent for females and males respectively. Phrased in terms of multiples of birth size, the upper limb length of the average 17-year-old female is three and one-fifth times that of the average female "at term." Comparably for males, average upper limb length at 17 is roughly three and two-fifths times that at birth.

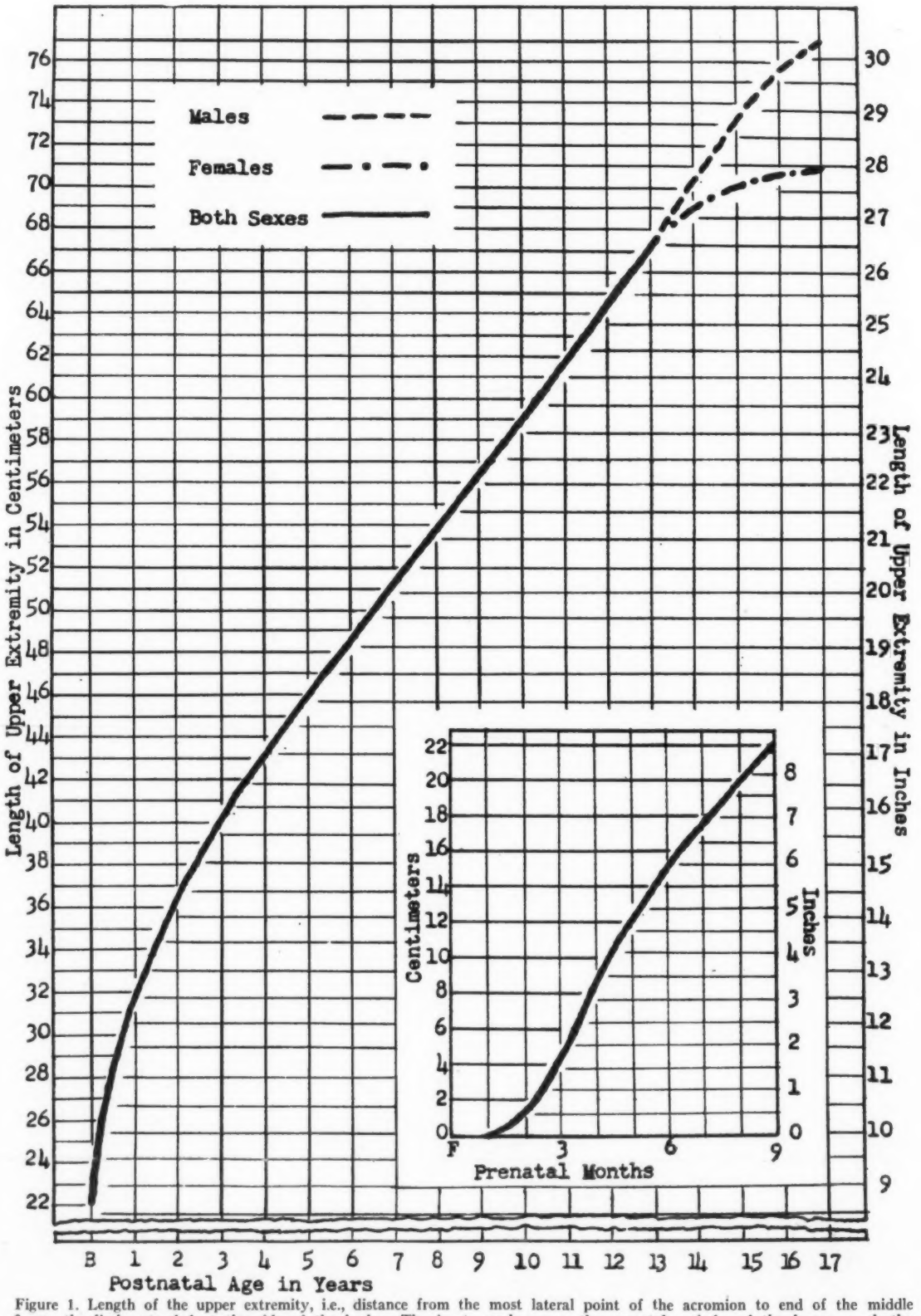
Males
Females
Both Sexes
Length of Upper Extremity in Centimeters
Length of Upper Extremity in Inches
Postnatal Age in Years
B 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Centimeters
Inches
Prenatal Months
F 3 6 9

Figure 1. Length of the upper extremity, i.e., distance from the most lateral point of the acromion to end of the middle finger, the limb extended at the side of the body. The inset graph covers the prenatal period and the larger graph the first 17 postnatal years: the solid lines are drawn to averages for both sexes combined, the dash line to averages for males and the dot-dash line to averages for females. The subjects represented are North American White children (largely children of northwest European ancestry and "above average" socioeconomic status) studied between 1920 and 1945.

per cent between 0.6 and 1.0 inches above, and 10 per cent between 1.0 and 1.9 inches above. Similarly, in relation to the average for a given sex at age 10 years, 10 per cent each lie between 3.0 and 1.5 inches below and above, 15 per cent each between 1.5 and 0.7 inches below and above, and 25 per cent each between 0.7 and 0.0 inches below and above. Roughly, 50 per cent of males cluster within zones of 1.7 inches at 12 years, 2.1 inches at 15 years, and 1.9 inches at 17 years; the full range of normal variation for males at these ages approximates 6.5 inches, 8.0 inches, and 7.0 inches respectively. There is need for more information on female variability at ages 10 to 17 years: seemingly the female range (see Simmons) is similar to the foregoing male figure at 12 years, but no less than one inch smaller than the male figures for 15 and 17 years.

5. Physically normal White children (children reasonably homogeneous secularly, ethnically, socioeconomically, and geographically) show decided individual dfferences in rate of growth of upper limb length. Absolute and relative gains of individuals over the age period 4 to 6 years have been found to differ by as much as one inch and seven per cent; corresponding variations among individuals over the age period 8 to 12 years approximate two inches and nine per cent (Meredith '46). Individual records which are all clearly below the normal range have been reported at ages between 6 and 18 years on a small series of dwarfs—chondrodystrophic, Mongoloid, microcephalic, cretinous, and ateliotic (Davenport). Upper extremities "shorter than normal" were also found by Grover from measurement of two "Mongoloid idiots" and two "cases of cretinism" at ages between 3 and 14 years.

6. (a) There is evidence that during recent decades an increase has occurred in the upper limb length of North American White children: it is estimated that average upper limb length was shorter at age 9 years in 1920 than in 1940 by one-half inch (Palmer, Meredith '46), and shorter at age 14 years in 1895 than in 1945 by more than one and one-half inches (Hall, Meredith '47). (b) Throughout the elementary and high school years average length of the superior limb is greater in children of Finnish ancestry than in children of Italian ancestry—the difference approximates two-fifths inch at ages 6 to 9 years and one-half inch at ages 14 to 17 years (Matheny and Meredith). Davenport, without presenting his evidence, reports:

"Negro children have upper limbs 2 to 6 cm. longer than whites." (c) Compared with the average values for upper limb length in normal children from Figure 1, average upper limb length is shorter for high-grade feebleminded children 6 to 17 years of age by about one inch, and shorter for 16-year-old Mongoloid dwarfs by more than four inches (Davenport). (d) The right upper limb tends to be slightly shorter than the left: averages for the preschool years register only a trace of difference (Iowa Child Welfare Research Station), while averages for the high school years register a difference of one-sixth inch.

Summary

This paper deals with the growth of North American children in length of the upper extremities. It constitutes a review and synthesis of the presently available research on the problem. The source materials utilized are drawn from twenty-eight separate studies—five previously unpublished.

Following an introductory sketch of growth during prenatal life, the paper is divided into three sections: "The Neonatal Period"; "Infancy"; "Childhood and Adolescence." The procedure employed in each section is that of first presenting the relevant investigations and then epitomizing their combined contribution to different aspects of the problem. Consideration is given to analyses of both cross-sectional and longitudinal data. Findings are pooled and integrated with reference to such variables as sex, birth order, prematurity, race, socioeconomic status, and secular period.

In addition to summarizing what is known regarding growth in superior limb length, the paper focuses attention upon methodological shortcomings and research gaps. The loss to science which has resulted from lack of a standardized anthropometric technique is forcefully portrayed. Research needs become apparent at many points; it will suffice here to cite the need for studies on children of non-White ethnic groups, and on children residing in families of low socioeconomic status.

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THE EFFECT OF 2, 4-DINITROPHENOL ON THE LARVAL GROWTH OF DROSOPHILA MELANOGASTER

DOROTHY THORNTON

Wellesley College, Wellesley, Massachusetts

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GROWTH IN DROSOPHILA

In this investigation the discontinuous nature of growth was studied by altering normal growth metabolism. Specifically, the purpose was to observe the effect of the drug dinitrophenol on the larval growth of *Drosophila melanogaster*. Larvae were used, since during the larval period growth is relatively simple to measure and experimental conditions are more easily controlled.

Previous investigation using nitrophenols and related compounds have established several facts concerning the biological action of dinitrophenol. Dinitrophenol increases the intracellular oxidative metabolism of both plant and animal tissues (Hall, Field, Sahyun, Cutting, and Tainter, 1933; Clowes and Krahl, 1934; McCord, 1934; and Garrey and Boykin, 1935). It is known that the action is directly on the cell and is independent of the nervous system and endocrine glands. The experiments of Hall, Field, Sahyun, Cutting and Tainter (1933), Muntwyler (1934), and Cutting, Mehrtens, and Tainter (1933) show that the principal fuel for the accelerated metabolism caused by dinitrophenol is not carbohydrate, but protein and fat.

MATERIALS AND METHODS

The first series of experiments were designed to test the effect of dinitrophenol in a concentration of M/2000. Three groups of larvae were used. The control group received no dinitrophenol and 10 gm. of yeast per 100 cc. of medium, while the two test groups received M/2000 dinitrophenol. The Test 1 group received the same amount of yeast as the controls and the Test 2 group received a double amount, or 20 gm. of yeast per 100 cc. medium. This procedure was repeated,

TABLE 1
PLAN OF EXPERIMENTS

Experiment number	Group	Amount of yeast	Concentration of D.N.P.
I	Control	10 g.	
	Test 1	10 g.	M/2000
	Test 2	20 g.	M/2000
II	Control	10 g.	
	Test 1	10 g.	M/2000
	Test 2	10 g.	M/1000
III	Control	10 g.	
	Test 1	10 g.	M/2000
IV	Control	10 g.	
	Test 1	20 g.	M/2000
V	Control	10 g.	
	Test 1	20 g.	M/2000
VI	Control	10 g.	
	Test 1	10 g.	M/1000
VII	Control	10 g.	
	Test 1	10 g.	M/1000
	Test 2	20 g.	M/1000

using dinitrophenol in a concentration of M/1000. Table 1 illustrates the plan of the experiments. Preliminary experiments showed that the concentrations of M/2000 and M/1000 produced a measurable effect without any toxic results and that normal but not maximal growth resulted when larvae were raised on 10 gm. of yeast per 100 cc. of medium.

The addition of dinitrophenol to the test medium and in some experiments the amount of yeast were the only experimental variations. All other conditions, such as the genetic constitution of the larvae, age of the larvae, light, temperature, and medium, were kept as constant as possible. In order to insure uniformity in the media it was necessary to carry out the experiments under sterile conditions, for the larvae were raised on a medium ideal for the growth of bacteria, yeasts, and molds. If any of the cultures became contaminated they were not used in the experiment. In order to measure differences in growth between groups of larvae, the larvae were raised to a given age, killed, and a record kept of the instar, length, and width of each animal.

A pure inbred stock of wild-type *Drosophila melanogaster* Swedish-b, was used. The stocks were raised on a standard medium (Birch, 1944) at 25°C. and kept in the dark. The eggs to be used in an experiment were collected in a two-hour period and sterilized

by the method described by Birch (1944). All glassware was washed in distilled water, dried, autoclaved at fifteen pounds pressure for twenty minutes, and dried overnight in an oven at 150°C.

The medium was prepared after the formula of Birch (1944). The following procedure was used to make up 100 cc. of the medium: 1.5 grams of agar, an amount of yeast (Fleishmann's) that varied with the experiment, 25 cc. of Solution A,* and 50 cc. of distilled water were mixed, heated, and one gram of sucrose added. After this mixture had been autoclaved for twenty minutes at fifteen pounds pressure, 25 cc. of Solution B* which had been sterilized in the same manner were mixed with the other substances.

The sodium salt of 2, 4-dinitrophenol was kindly supplied by Dr. E. E. Jones of Wellesley College. Since it is freely soluble in water, 5.601 grams of the salt were dissolved in 5 cc. of water to make a 0.1 M stock solution, which was kept in the dark. An amount of this sufficient to make a concentration of M/2000 or M/1000 was added to and mixed with the test medium.

In beginning an experiment the warm medium was pipetted into 5 cm. Petri dishes, 4 cc. of the medium to a dish. Five inch test tubes were used for larvae to be raised to more than 120 hours. When the medium had cooled and solidified, sterilized eggs, usually from 20-40 per dish, were added. The dishes and test tubes were kept in an incubator at 25°C. At each of four or five ages two or three dishes of larvae were killed by the method of Alpatov (1929) and preserved in 70 per cent alcohol. Measurements of length and width were made by using a calibrated ocular micrometer in a monocular microscope with a 48 mm. objective and a 10x ocular. The larva was measured from a lateral view. Length was measured and the instar determined by the method of Alpatov (1929). Width was measured at the seventh abdominal segment after the method of Brehme (1939). In one experiment observations were made on the duration of larval life. At four different times during the period when larvae were pupating counts were made of the number of pupae. The fourth and last count was made when all larvae had pupated.

*Solutions A and B were salt solutions modified after Schader (1941):

Solution A		*Solution B*	
ammonium sulfate	2.0 g.	tartaric acid	2.5 g.
magnesium sulfate	0.5 g.	potassium dihydrogen phosphate	0.65 g.
distilled water	250 cc.	distilled water	250 cc.

For both length and width of each group of larvae the mean and the standard error of the mean were computed. In comparing two groups, the difference between their two means was considered significant if this difference was three or more times the standard error of the difference between the two means.

Results and Discussion

I. The effect of a concentration of M/2000 dinitrophenol on larvae fed 10 grams of yeast per 100 cc. of medium.

Table 2 and the growth curves in Figures 1 and 2 illustrate the retarding effect of dinitrophenol on size increase. At all ages except 120 hours the mean length and the mean width of the Test 1 group were less than those of the control group and this difference was significant. The growth curve for normal larvae shows a constant increase in size and then a slight decrease after the maximum is reached. This growth curve is not greatly altered in the test larvae, but they do definitely grow at a slower rate. The effect of dinitro-

TABLE 2
Average Length and Width of Larvae
(*Experiment I*)

Control—10 g. yeast per 100 cc.
Test 1—10 g. yeast per 100 cc. + M/2000 D.N.P.

Age *	Group	No.		Length in mm.		Width in mm.
47	Control	34		1.59±.042		.26±.066
	Test 1	38		1.46±.015		.22±.004
	Difference		=	.13±.042	=	.04±.007
72	Control	46		3.19±.037		.51±.007
	Test 1	49		2.64±.045		.40±.007
	Difference		=	.55±.059	=	.11±.010
96	Control	41		4.89±.092		.80±.017
	Test 1	37		4.07±.075		.63±.015
	Difference		=	.82±.119	=	.17±.023
104.5	Control	39		5.34±.043		.88±.006
	Test 1	55		4.90±.041		.77±.009
	Difference		=	.44±.060	=	.11±.012
120	Control	27		4.96±.046		.87±.011
	Test 1	40		5.07±.086		.86±.015
	Difference		=	.11±.111	=	.01±.020

*Age in hours from the median hour of egg-laying.

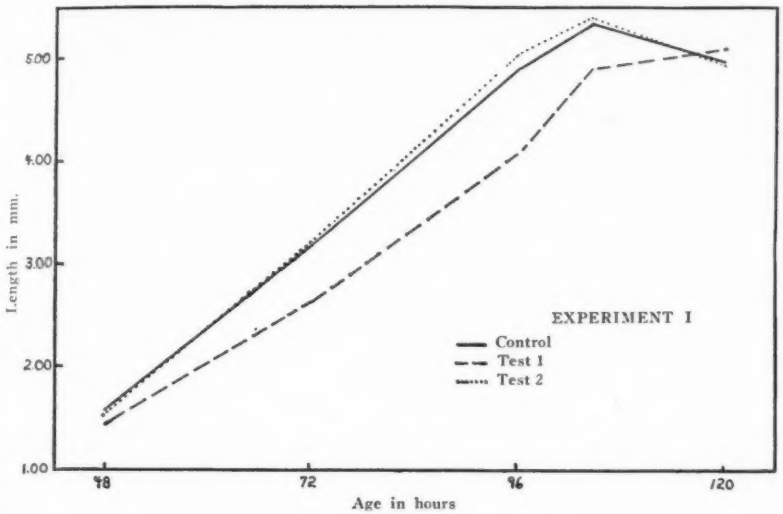

FIGURE 1

GROWTH IN LENGTH OF LARVAE FED ON M/2000 DINITROPHENOL

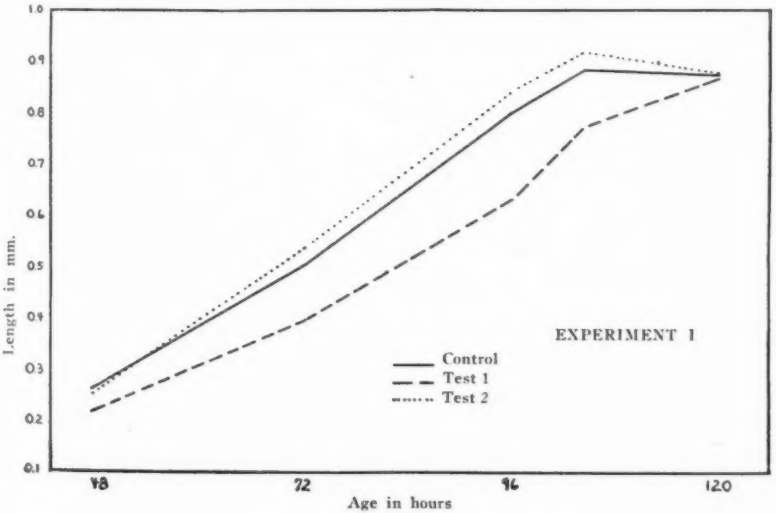

FIGURE 2

GROWTH IN WIDTH OF LARVAE FED ON M/2000 DINITROPHENOL

phenol observed here can be explained by the results of previous investigations. They indicate that the dinitrophenol causes an increased intracellular oxidative metabolism, an increased requirement of fuel, and a depletion of protein and fat stores to meet this need, thus leaving less material available for growth. Records of the time of molting and pupation of larvae indicate that the test larvae molt at later ages and that their larval life is extended.

II. The effect of a concentration of M/2000 dinitrophenol on larvae fed 20 grams of yeast per 100 cc. of medium, twice the amount of yeast fed the control larvae.

In three experiments (I, IV, and V) a control group was fed 10 grams of yeast per 100 cc. of culture medium and a test group was fed 20 grams of yeast and a concentration of M/2000 dinitrophenol in each 100 cc. of medium. It is obvious from Figures 1 and 2 that the retarding effect of dinitrophenol on length and width was largely overcome by the increase in the supply of available food. In the test larvae there was only an initial retardation in time of molting and pupation. That the effect of dinitrophenol on size, on molting, and on pupation may be compensated for in part by ingestion of additional food is evidence that the drug is not toxic at this concentration. Its effect, then, is the depletion of material available for growth and development.

III. The effect of a concentration of M/1000 dinitrophenol on larvae fed 10 grams of yeast per 100 cc. of medium.

Retardation of growth was more marked with a concentration of M/1000 than with a concentration of M/2000, as illustrated by Experiment II (Figure 3 and Table 3). At all ages the mean length and the mean width of the Test 2 group were significantly less than those of the Test 1 group. Larval instars were more prolonged by a concentration of M/1000 than by a concentration of M/2000. At 97 hours 97.2% of the control larvae, 92.3% of the Test 1 larvae, and 18.3% of the Test 2 group had molted twice.

IV. The effect of a concentration of M/1000 dinitrophenol on larvae fed 20 grams of yeast per 100 cc. of medium, twice the amount received by the control group.

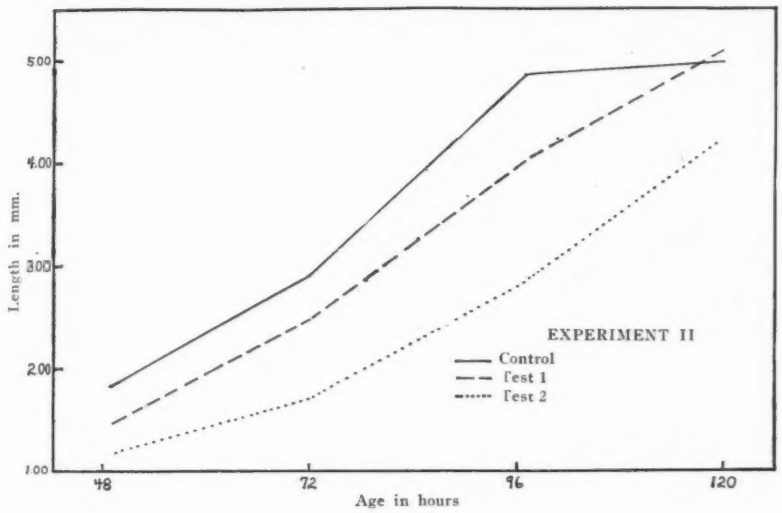

FIGURE 3

GROWTH IN LENGTH OF LARVAE FED ON M/2000 AND M/1000 DINITROPHENOL

TABLE 3

AVERAGE LENGTH AND WIDTH OF LARVAE

(*Experiment II*)

Test 1—10 g. yeast per 100 cc. + M/2000 DNP
Test 2—10 g. yeast per 100 cc. + M/1000 DNP

Age	Group	No.	Length in mm.	Width in mm.
49	Test 1	54	1.47±.034	.22±.003
	Test 2	67	1.17±.038	.19±.005
	Difference	=	.30±.053 =	.03±.007
72	Test 1	114	2.48±.021	.37±.005
	Test 2	52	1.71±.071	.27±.010
	Difference	=	.77±.057 =	.10±.010
97	Test 1	130	4.02±.045	.62±.007
	Test 2	71	2.85±.089	.44±.013
	Difference	=	1.17±.090 =	.18±.014
120	Test 1	105	5.10±.060	.82±.011
	Test 2	70	4.23±.113	.66±.017
	Difference	=	.87±.118 =	.16±.019

In one experiment, Experiment VII, M/1000 dinitrophenol was fed to two groups. The Test 1 group received 10 grams of yeast and the Test 2 group received 20 grams. Table 4 and Figure 4 indicate a

TABLE 4
AVERAGE LENGTH AND WIDTH OF LARVAE
(*Experiment VII*)

Test 1—10 g. yeast per 100 cc. + M/1000 DNP
Test 2—20 g. yeast per 100 cc. + M/1000 DNP

Age	Group	No.	Length in mm.	Width in mm.
48	Test 1	65	1.07±.024	.18±.002
	Test 2	68	1.38±.021	.18±.004
	Difference		= .31±.032	= .00±.004
72	Test 1	44	1.49±.053	.24±.008
	Test 2	59	2.61±.045	.39±.008
	Difference		= 1.12±.070	= .15±.011
96	Test 1	52	2.62±.091	.42±.012
	Test 2	99	4.21±.046	.64±.008
	Difference		= 1.59±.092	= .22±.014
120	Test 1	39	3.62±.171	.54±.025
	Test 2	82	5.29±.027	.88±.005
	Difference		= 1.67±.124	= .34±.019

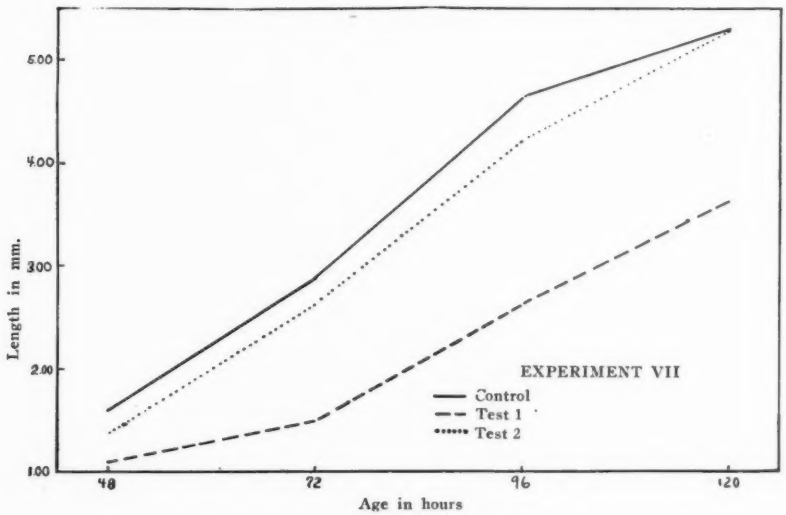

FIGURE 4
GROWTH IN LENGTH OF LARVAE FED ON M/1000 DINITROPHENOL

significant increase in both length and width of Test 2 larvae over Test 1 larvae. The increased amount of yeast had a marked accelerating effect on molting. At 72 hours 100% of the controls, 29.5% of the Test 1 group, and 96.6% of the Test 2 group had molted once. At 96 hours 100% of the controls, 3.8% of the Test 1 group, and 91.9% of the Test 2 group had molted twice.

In experiments with a double amount of yeast at both concentrations the retarding effect of dinitrophenol was evident at an early age and was completely or partly overcome later. This was exhibited in molting as well as in reduction of length and width. The effect of dinitrophenol was quantitative, since a concentration of M/1000, in comparison with a concentration of M/2000, had a similar but heightened effect on growth.

Summary

1. Dinitrophenol in concentrations of M/2000 and M/1000 decreased the rate of growth and delayed molting and pupation in larvae of *Drosophila melanogaster*.

2. The retarding effect of dinitrophenol on body size, molting, and pupation was lessened by feeding the test larvae twice as much food as the control group.

3. The effect of dinitrophenol on body size, molting, and pupation may be attributed to an increase in intracellular oxidative metabolism which in turn results in a conversion of stored fat and protein to energy.

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CORRELATIONS OF ORGAN WEIGHTS WITH BODY WEIGHT, BODY LENGTH AND WITH OTHER WEIGHTS IN THE ADULT CAT

HOMER B. LATIMER

Department of Anatomy, University of Kansas

The body weight, body length and the weights of most of the organs of the adult cat, together with their usual biometric constants have been published. With these data have been published the correlations between some of the organ weights and the body weight and also the correlations between a few of the weights of the various organs. This report will attempt to show all of the correlations between the weights of the organs and the body weight, the body length and also the weights of each organ correlated with each of the other organs. It is hoped that this study will give some idea of the quantitative relationships between the various organs and also between the body weight, body length and the organ weights. Of course, a corresponding increase, or decrease, in the size of an organ would mean a corresponding increase or decrease in function only if all of the other factors, of which we have no knowledge in this study, were to remain the same. Changes in the histological structure, or the physiological action could invalidate these relationships, based wholly on size.

An organ having more than one function, such as the pancreas, the suprarenals or the hypophysis might not be as well correlated with other organ weights, as one having but a single function. However, these quantitative relationships should give us some idea of the size of the various organs with reference to the size of the other organs and also with respect to the body weight, and body length.

In searching the literature for the coefficients of correlation in man and in other animals, a surprisingly small amount of data was found. There are many records of weights and also coefficients of variation, but not many coefficients of correlation. Greenwood (1904) and Greenwood and Brown (1913) give coefficients of correlation for

four organs of the human body with body weight and the interorgan correlations. Pearl (1905) gives the weight of the human brain correlated with many of the organs of the body. Schuster (1911) has correlated many of the external dimensions of the body but gives no correlations for any of the weights of the organs. Likewise Orensteen (1916) has correlated some of the anthropometrical external measurements of the human body.

Jackson (1913) has correlated the weights of most of the viscera with the body weight of the albino rat at seven periods of growth, from birth to maturity. Hammett (1925) gives correlations between the various endocrine glands in the adult white rat. Correlations between body weight and organ weight and correlations between some of the organ weights have been studied in the frog, turtle and turkey hen by Latimer (1920, 1927), and by Latimer and Pedersen (1923) for the chicken. Correlation of the body weight and the body length with the brain and its major parts and with the weight and length of the cord have been studied in the dog (Latimer 1942a). Correlations of the weights and the linear dimensions of the various parts of the skeleton of the muskrat are given by Latimer and Riley (1934). Similar correlations for the skull and long bones of the skunk are given by Latimer (1937b), for the mourning dove (Latimer and Asling, 1938), for the red-tailed hawk (Latimer, 1938a), and for the mallard duck by Latimer and Wager (1941).

The 28 external linear dimensions of the adult cats used in this study were correlated with body length. The weights of the head, trunk, fore limbs and hind limbs were correlated with body length and body weight (Latimer, 1936). The statistical data on the weights of the organs used in the tables which follow are given in the series of papers listed in the literature (see references). A few of the correlations have been taken from these papers, but most were worked out for this study.

Correlations With Body Weight and Body Length

The correlations of the various organs with body weight and with body length for both the males and the females are shown in Table 1. All of the correlations in this table are positive, though some are too low to be significant, and hence all signs are omitted. Likewise, in all of the following tables and in the text, all correlations are positive

and so all signs are omitted. The correlations are higher on the average for the males than for the females, and in each sex, the average correlations are higher with body weight. These average correlations are shown in the bottom line in this table. The average of the correlations between the organ weights and the body weight is 12 per cent greater in the males than in the females, and the males are likewise better correlated on the average with the body length by 14 per cent. The organs in the males are better correlated with body weight than with body length by 13 per cent and the similar averages in the females are 14 per cent greater. In other words, the average correlations are better in the males than in the females and also better with body weight than with body length.

TABLE 1
CORRELATIONS WITH BODY WEIGHT AND BODY LENGTH

	Males		Females	
	Body weight	Body length	Body weight	Body length
Integument	0.974±0.004	0.845±0.027	0.945±0.010	0.673±0.051
Skeleton	0.783±0.037	0.758±0.041	0.550±0.068	0.554±0.067
Musculature	0.978±0.004	0.777±0.038	0.917±0.015	0.520±0.071
Heart	0.849±0.026	0.732±0.043	0.868±0.023	0.796±0.034
Spleen	0.646±0.055	0.470±0.073	0.616±0.059	0.371±0.081
Brain	0.370±0.081	0.226±0.089	0.317±0.084	0.461±0.074
Sp. cord	0.679±0.050	0.658±0.053	0.612±0.059	0.767±0.038
Eyeballs	0.756±0.040	0.748±0.041	0.505±0.070	0.682±0.050
Dig. tube W.	0.734±0.043	0.692±0.049	0.507±0.070	0.477±0.073
Dig. tube L.	0.429±0.076	0.465±0.073	0.459±0.074	0.386±0.080
Liver	0.662±0.053	0.580±0.062	0.591±0.061	0.474±0.073
Pancreas	0.498±0.070	0.364±0.081	0.660±0.053	0.561±0.064
Lungs	0.669±0.060	0.751±0.048	0.736±0.052	0.668±0.062
Kidneys	0.837±0.028	0.593±0.061	0.868±0.023	0.734±0.043
Bladder	0.788±0.035	0.851±0.026	0.503±0.070	0.448±0.075
Gonads	0.828±0.029	0.737±0.043	0.687±0.050	0.149±0.097
Uterus	———	———	0.506±0.070	0.607±0.062
Thyroid	0.780±0.037	0.645±0.055	0.419±0.078	0.298±0.087
Suprarenals	0.635±0.056	0.526±0.068	0.561±0.064	0.647±0.055
Hypophysis	0.189±0.091	0.165±0.092	0.434±0.077	0.465±0.074
Average	0.689	0.610	0.613	0.537

The four organs, or systems, which are best correlated with the body weight in both sexes are the musculature, the integument, the heart and the kidneys. There are four correlations for both the males and the females with body weight which are below 0.5. The length of the digestive tube, the weights of the brain, and the hypophysis are found in this group in both sexes. In the males, the fourth

organ is the pancreas. The pancreas is seventh in order of decreasing correlations in the females. In the females, the thyroid is the fourth organ below 0.5 and it is next to the lowest correlation. The thyroid is eighth in order of decreasing correlations in the males.

The position of the higher four correlations is easily understood, because these form large divisions of the body, or else their function is very closely associated with all parts of the body. The correlations of the gonads is surprisingly high. In the males, the testis is fifth and in the females, the ovary is sixth in order of the correlations with the body weight. In the rat, Jackson (1913) finds the correlations between the body weight and the weight of the gonads "higher than might be anticipated from their variability in weight." The brain in the cat, as has been reported for the dog (Latimer, 1942a), seems to be more independent of the body weight than most of the other organs. The correlation of the brain weight and the body weight is next to the lowest correlation in the males and the lowest in the females. In both sexes the spinal cord and the eyeballs are better correlated with body weight than is the brain. Jackson (1913) finds that the liver has one of the best correlations in the rat, but in the cat, it is thirteenth in order in the male and tenth in the female.

The average of the correlations, or 0.613, with body weight for the female cats is very slightly lower than that reported for the average correlation of 0.646 between the body weight and sixteen organs in the turkey hen (Latimer, 1927). The average of the correlations with the body weight for four organs: heart, kidneys, liver and brain for man is given as 0.46 by Greenwood and Brown (1913). Jackson (1913) gives an average of 0.70 for the correlations of thirteen organs with body weight in the albino rat. The average of eight organs in the turtle, correlated with body weight is 0.456 and the average of similar correlations of six organs of the frog, is 0.814 (Latimer, 1920). Of the four organs correlated with body weight reported by Greenwood and Brown, the lowest correlation of 0.25, is with the brain and the highest, or 0.65, is with the heart.

The correlations with the body length are not as high as those with the body weight. The differences in the averages have already been given. The highest correlation with body length in the males, is that with the bladder, but it is only 0.851, and the best correlation in the females is with the heart weight (0.796). In the males, there

are five correlations with the body weight above 0.8 and with body length there are but two. For the females, there are four correlations of 0.8 or above with the body weight and none with the body length of so high a value. The highest correlation with the female body length is 0.796 for the heart. Instead of the four correlations below 0.5 in each sex with the body weight, there are five with the body length in the males and nine in the females. Hence the body weight gives on the whole a far better idea of the weights of most of the organs than does the body length.

In an earlier report (Latimer, 1936) 28 linear dimensions of these cats were correlated with body length and it is interesting to see that these linear dimensions have a slightly higher average correlation with the body length than the weights of these organs. For the male cats, the organs have a correlation of 0.610, and the linear dimensions, an average of 0.649. The similar average correlations for the females are respectively, 0.537 and 0.599.

Thus in both the linear dimensions as well as in the weights of the organs, the correlations are on the average higher in the male cats. There are 22 correlations in Table 1 below 0.5 and nine of these are found in the males and 13 in the females. The linear dimensions are, on the average, slightly better correlated with body length than the weights of the organs.

Correlations Between the Organs

Tables 2 and 3 give the correlations between each organ and each of the other organs. The bottom line gives the average of the correlations of the one organ and the other eighteen, or for the females, the other 19 organs. All of the 361 correlations are positive and so all the signs have been omitted from these tables. The average of the 171 male correlations in Table 2 is 0.546 and the average of the 190 female correlations given in Table 3 is 0.450, or the average of all the male interorgan correlations is 21.3 per cent greater than the similar average for the females. There are 67 of the 171 male interorgan correlations, or 39.1 per cent, that are below 0.5 per cent, or are not sufficiently high to be valid correlations. Of the 190 female correlations shown in Table 3, 111 or 58.42 per cent are below 0.5. The correlation between the spleen and the hypophysis in the males is but 0.081 and with a probable error of 0.094. This correlation is too

low to be significant and also its probable error is larger than the correlation itself. The correlation between the weights of the thyroid and the brain in the female cats is still lower, or 0.004 ± 0.094. Its probable error is over 23 times greater than the correlation itself. There are many other correlations too low to be significant.

There is a good deal of variation in the individual correlations. The highest in the males is 0.938 between the bladder and the weight of the entire digestive tube. In the males there are six correlations of 0.9 or above. In the females, there is but one correlation above 0.9 and this is 0.964, between the kidneys and the weights of the musculature. This is the highest correlation found between any two organs in either sex. The similar correlation for the males is 0.844 ± 0.027, or as is to be expected from the physiological relationship, there is close relationship between the weights of the musculature and the kidneys in both sexes. There are four correlations in the females between 0.8 and 0.9 and sixteen correlations in the males having the same numerical range.

There are three correlations below 0.1 in the males and the lowest is 0.048 ± 0.093, between the hypophysis and the eyeballs. In the females, there are four correlations below 0.1 and the lowest of these is 0.004 ± 0.094 between the thyroid and the brain.

In the male cats the organ having the highest average correlation with all of the other organs is the bladder with an average correlation of 0.730. The heart and the integument tie for second place with an average correlation of 0.684. The brain has next to the lowest average correlation, or 0.317, and the lowest in the males is the hypophysis with an average of 0.177. In the females the organ having the highest average correlation with the other organs is the heart with an average of 0.616. The second highest is the kidney with an average of 0.614. The bladder which is highest in the males is in the fourteenth place in order of rank in the females and the integument which is second in the males is in the third place in the list of female interorgan correlations. The organ having the lowest average correlation in the females is the thyroid with an average of 0.240. Next to the lowest is the brain with a correlation of 0.302. The brain is next to the lowest in the list of average interorgan correlations in both sexes. Thus there is quite a difference in the average correlations of some of the organs in the two sexes, as well as a wide range in the individual correlations.

TABLE 2

CORRELATIONS, ADULT MALE CATS

	Integument	Skeleton	Musculature	Heart	Spleen	Brain	Sp. cord	Eyeballs	Dig. T. Wgt.	Dig. T. L.	Liver	Pancreas	Lungs	Kidneys	Bladder	Testes	Thyroid	Suprarenals
Integument		0.812±0.032	0.913±0.016	0.892±0.019	0.603±0.060	0.394±0.079	0.733±0.043	0.799±0.034	0.719±0.045	0.437±0.076	0.602±0.060	0.535±0.067	0.653±0.063	0.860±0.024	0.930±0.013	0.816±0.031	0.786±0.036	0.670±0.052
Skeleton	0.812±0.032		0.662±0.054	0.722±0.046	0.395±0.080	0.516±0.070	0.866±0.024	0.755±0.041	0.755±0.041	0.578±0.063	0.470±0.074	0.415±0.080	0.825±0.036	0.715±0.046	0.816±0.032	0.607±0.060	0.564±0.065	0.669±0.053
Musculature	0.913±0.016	0.662±0.054		0.908±0.017	0.609±0.060	0.248±0.090	0.527±0.069	0.673±0.052	0.641±0.056	0.340±0.084	0.607±0.060	0.557±0.066	0.611±0.070	0.844±0.027	0.870±0.023	0.879±0.022	0.690±0.050	0.613±0.060
Heart	0.892±0.019	0.722±0.046	0.908±0.017		0.645±0.055	0.336±0.083	0.652±0.054	0.724±0.044	0.678±0.051	0.522±0.068	0.778±0.037	0.581±0.063	0.594±0.071	0.912±0.016	0.868±0.023	0.847±0.026	0.796±0.034	0.641±0.055
Spleen	0.603±0.060	0.395±0.080	0.609±0.060	0.645±0.055		0.099±0.093	0.242±0.088	0.475±0.072	0.446±0.075	0.234±0.088	0.367±0.081	0.367±0.081	0.363±0.095	0.618±0.058	0.713±0.046	0.572±0.063	0.405±0.078	0.491±0.072
Brain	0.394±0.079	0.516±0.070	0.248±0.090	0.336±0.083	0.099±0.093		0.617±0.058	0.475±0.072	0.355±0.082	0.395±0.079	0.394±0.079	0.160±0.091	0.103±0.108	0.323±0.084	0.237±0.088	0.232±0.089	0.230±0.089	0.376±0.080
S. cord	0.733±0.043	0.866±0.024	0.527±0.069	0.652±0.054	0.242±0.088	0.617±0.058		0.756±0.040	0.630±0.056	0.455±0.074	0.567±0.063	0.268±0.087	0.593±0.071	0.592±0.061	0.702±0.047	0.575±0.063	0.572±0.063	0.584±0.062
Eyeballs	0.799±0.034	0.755±0.041	0.673±0.052	0.724±0.044	0.475±0.072	0.475±0.072	0.756±0.040		0.661±0.053	0.341±0.079	0.731±0.044	0.482±0.072	0.451±0.087	0.760±0.040	0.922±0.014	0.739±0.042	0.618±0.058	0.743±0.042
Dig. tube, wgt.	0.719±0.045	0.755±0.041	0.641±0.056	0.678±0.051	0.446±0.075	0.355±0.082	0.630±0.056	0.661±0.053		0.647±0.054	0.652±0.054	0.597±0.060	0.566±0.074	0.649±0.054	0.938±0.011	0.574±0.063	0.534±0.067	0.608±0.059
Dig. tube, L.	0.437±0.076	0.578±0.063	0.340±0.084	0.522±0.068	0.234±0.088	0.395±0.079	0.455±0.074	0.341±0.079	0.647±0.054		0.641±0.055	0.385±0.080	0.447±0.088	0.433±0.076	0.555±0.065	0.294±0.085	0.290±0.086	0.390±0.079
Liver	0.602±0.060	0.470±0.074	0.607±0.060	0.778±0.037	0.367±0.081	0.394±0.079	0.567±0.063	0.731±0.044	0.652±0.054	0.641±0.055		0.534±0.067	0.498±0.082	0.738±0.043	0.819±0.031	0.665±0.052	0.599±0.060	0.560±0.064
Pancreas	0.535±0.067	0.415±0.080	0.557±0.066	0.581±0.063	0.367±0.081	0.160±0.091	0.268±0.087	0.482±0.072	0.597±0.060	0.385±0.080	0.534±0.067		0.308±0.100	0.581±0.062	0.729±0.044	0.490±0.071	0.431±0.076	0.478±0.072
Lungs	0.653±0.063	0.825±0.036	0.611±0.070	0.594±0.071	0.363±0.095	0.103±0.108	0.593±0.071	0.451±0.087	0.566±0.074	0.447±0.088	0.498±0.082	0.308±0.100		0.554±0.076	0.494±0.083	0.444±0.088	0.607±0.069	0.366±0.095
Kidneys	0.860±0.024	0.715±0.046	0.844±0.027	0.912±0.016	0.618±0.058	0.323±0.084	0.592±0.061	0.760±0.040	0.649±0.054	0.433±0.076	0.738±0.043	0.581±0.062	0.554±0.076		0.863±0.024	0.747±0.041	0.794±0.035	0.742±0.042
Bladder	0.930±0.013	0.816±0.032	0.870±0.023	0.868±0.023	0.713±0.046	0.237±0.088	0.702±0.047	0.922±0.014	0.938±0.011	0.555±0.065	0.819±0.031	0.729±0.044	0.494±0.083	0.863±0.024		0.863±0.024	0.688±0.049	0.821±0.030
Testes	0.816±0.031	0.607±0.060	0.879±0.022	0.847±0.026	0.572±0.063	0.232±0.089	0.575±0.063	0.739±0.042	0.574±0.063	0.294±0.085	0.665±0.052	0.490±0.071	0.444±0.088	0.747±0.041	0.863±0.024		0.641±0.055	0.642±0.055
Thyroid	0.786±0.036	0.564±0.065	0.690±0.050	0.796±0.034	0.405±0.078	0.230±0.089	0.572±0.063	0.618±0.058	0.534±0.067	0.290±0.086	0.599±0.060	0.431±0.076	0.607±0.069	0.794±0.035	0.688±0.049	0.641±0.055		0.463±0.075
Suprarenals	0.670±0.052	0.669±0.053	0.613±0.060	0.641±0.055	0.491±0.072	0.376±0.080	0.584±0.062	0.743±0.042	0.608±0.059	0.390±0.079	0.560±0.064	0.478±0.072	0.366±0.095	0.742±0.042	0.821±0.030	0.642±0.055	0.463±0.075	
Hypophysis	0.161±0.091	0.231±0.091	0.170±0.094	0.212±0.090	0.081±0.094	0.214±0.090	0.165±0.092	0.048±0.093	0.181±0.090	0.282±0.086	0.293±0.086	0.132±0.092	0.170±0.108	0.155±0.091	0.275±0.086	0.128±0.093	0.160±0.092	0.124±0.093
Average	0.684	0.632	0.631	0.684	0.429	0.317	0.553	0.620	0.602	0.426	0.584	0.446	0.473	0.660	0.730	0.604	0.568	0.557

TABLE 3

CORRELATIONS ADULT FEMALE CATS

	Integument	Skeleton	Musculature	Heart	Spleen	Brain	Sp. cord	Eyeballs	Dig. T. Wgt.	Dig. T. L.	Liver	Pancreas	Lungs	Kidneys	Bladder	Ovaries	Uterus	Thyroid	Supra
Integument		0.590±0.063	0.894±0.020	0.826±0.030	0.579±0.062	0.284±0.086	0.600±0.060	0.571±0.063	0.456±0.074	0.419±0.077	0.517±0.069	0.566±0.064	0.732±0.052	0.811±0.032	0.592±0.061	0.636±0.056	0.468±0.073	0.364±0.081	0.546
Skeleton	0.590±0.063		0.410±0.081	0.587±0.064	0.273±0.090	0.231±0.092	0.684±0.052	0.560±0.067	0.566±0.066	0.292±0.089	0.395±0.082	0.352±0.085	0.521±0.086	0.594±0.063	0.365±0.084	0.401±0.083	0.276±0.095	0.279±0.090	0.488
Musculature	0.894±0.020	0.410±0.081		0.754±0.042	0.609±0.061	0.279±0.090	0.416±0.081	0.384±0.083	0.403±0.082	0.392±0.082	0.521±0.071	0.555±0.067	0.520±0.086	0.964±0.007	0.405±0.081	0.727±0.046	0.436±0.083	0.349±0.086	0.501
Heart	0.826±0.030	0.587±0.064	0.754±0.042		0.559±0.064	0.413±0.077	0.737±0.043	0.612±0.059	0.561±0.064	0.524±0.068	0.621±0.058	0.656±0.053	0.706±0.056	0.886±0.020	0.432±0.076	0.526±0.068	0.647±0.057	0.413±0.078	0.720
Spleen	0.579±0.062	0.273±0.090	0.609±0.061	0.559±0.064		0.182±0.090	0.342±0.083	0.210±0.089	0.074±0.093	0.224±0.089	0.194±0.090	0.362±0.081	0.327±0.100	0.566±0.064	0.281±0.086	0.443±0.076	0.392±0.083	0.461±0.074	0.289
Brain	0.284±0.086	0.231±0.092	0.279±0.090	0.413±0.077	0.182±0.090		0.567±0.063	0.454±0.074	0.246±0.088	0.252±0.088	0.311±0.085	0.188±0.090	0.339±0.127	0.289±0.086	0.272±0.087	0.220±0.089	0.331±0.083	0.004±0.094	0.358
Sp. cord	0.600±0.060	0.684±0.052	0.416±0.081	0.737±0.043	0.342±0.083	0.567±0.063		0.688±0.049	0.573±0.063	0.403±0.078	0.496±0.071	0.531±0.067	0.613±0.070	0.643±0.055	0.527±0.068	0.268±0.087	0.502±0.070	0.241±0.088	0.712
Eyeballs	0.571±0.063	0.560±0.067	0.384±0.083	0.612±0.059	0.210±0.089	0.454±0.074	0.688±0.049		0.536±0.057	0.355±0.082	0.408±0.078	0.478±0.072	0.665±0.063	0.657±0.053	0.504±0.070	0.239±0.088	0.599±0.060	0.138±0.092	0.725
Dig. tube, wt.	0.456±0.074	0.566±0.066	0.403±0.082	0.561±0.064	0.074±0.093	0.246±0.088	0.573±0.063	0.536±0.057		0.428±0.076	0.670±0.052	0.498±0.070	0.474±0.087	0.484±0.072	0.377±0.080	0.187±0.090	0.472±0.073	0.093±0.093	0.550
Dig. tube, L.	0.419±0.077	0.292±0.089	0.392±0.082	0.524±0.068	0.224±0.089	0.252±0.088	0.403±0.078	0.355±0.082	0.428±0.076		0.476±0.072	0.328±0.083	0.445±0.090	0.497±0.070	0.245±0.088	0.341±0.083	0.407±0.078	0.015±0.094	0.432
Liver	0.517±0.069	0.395±0.082	0.521±0.071	0.621±0.058	0.194±0.090	0.311±0.085	0.496±0.071	0.408±0.078	0.670±0.052	0.476±0.072		0.636±0.056	0.506±0.084	0.576±0.062	0.404±0.078	0.284±0.086	0.401±0.078	0.143±0.092	0.592
Pancreas	0.566±0.064	0.352±0.085	0.555±0.067	0.656±0.053	0.362±0.081	0.188±0.090	0.531±0.067	0.478±0.072	0.498±0.070	0.328±0.083	0.636±0.056		0.641±0.066	0.602±0.060	0.296±0.085	0.270±0.087	0.322±0.084	0.187±0.090	0.460
Lungs	0.732±0.052	0.521±0.086	0.520±0.086	0.706±0.056	0.327±0.100	0.339±0.127	0.613±0.070	0.665±0.063	0.474±0.087	0.445±0.090	0.506±0.084	0.641±0.066		0.751±0.049	0.535±0.080	0.395±0.095	0.348±0.102	0.225±0.107	0.556
Kidneys	0.811±0.032	0.594±0.063	0.964±0.007	0.886±0.020	0.566±0.064	0.289±0.086	0.643±0.055	0.657±0.053	0.484±0.072	0.497±0.070	0.576±0.062	0.602±0.060	0.751±0.049		0.551±0.065	0.666±0.053	0.599±0.060	0.349±0.082	0.701
Bladder	0.592±0.061	0.365±0.084	0.405±0.081	0.432±0.076	0.281±0.086	0.272±0.087	0.527±0.068	0.504±0.070	0.377±0.080	0.245±0.088	0.404±0.078	0.296±0.085	0.535±0.080	0.551±0.065		0.334±0.084	0.624±0.060	0.213±0.089	0.504
Ovaries	0.636±0.056	0.401±0.083	0.727±0.046	0.526±0.068	0.443±0.076	0.220±0.089	0.268±0.087	0.239±0.088	0.187±0.090	0.341±0.083	0.284±0.086	0.270±0.087	0.395±0.095	0.666±0.053	0.334±0.084		0.114±0.098	0.281±0.088	0.712
Uterus	0.468±0.073	0.276±0.095	0.436±0.083	0.647±0.057	0.392±0.083	0.331±0.083	0.502±0.070	0.599±0.060	0.472±0.073	0.407±0.078	0.401±0.078	0.322±0.084	0.348±0.102	0.599±0.060	0.624±0.060	0.114±0.098		0.240±0.094	0.599
Thyroid	0.364±0.081	0.279±0.090	0.349±0.086	0.413±0.078	0.461±0.074	0.004±0.094	0.241±0.088	0.138±0.092	0.093±0.093	0.015±0.094	0.143±0.092	0.187±0.090	0.225±0.107	0.349±0.082	0.213±0.089	0.281±0.088	0.240±0.094		0.332
Suprarenals	0.546±0.066	0.488±0.074	0.501±0.073	0.720±0.045	0.289±0.086	0.358±0.082	0.712±0.046	0.725±0.044	0.550±0.065	0.432±0.076	0.592±0.061	0.460±0.074	0.556±0.078	0.701±0.048	0.504±0.070	0.712±0.047	0.599±0.063	0.332±0.084	
Hypophysis	0.430±0.076	0.458±0.078	0.411±0.082	0.522±0.069	0.110±0.083	0.510±0.070	0.494±0.071	0.637±0.056	0.322±0.084	0.344±0.082	0.226±0.089	0.339±0.083	0.367±0.097	0.486±0.071	0.267±0.087	0.293±0.087	0.539±0.071	0.225±0.090	0.508
Average	0.573	0.438	0.523	0.616	0.341	0.302	0.528	0.496	0.419	0.359	0.441	0.435	0.509	0.614	0.407	0.386	0.438	0.240	0.541

Kidneys	Bladder	Testes	Thyr
360±0.024	0.930±0.013	0.816±0.031	0.786±
715±0.046	0.816±0.032	0.607±0.060	0.564±
344±0.027	0.870±0.023	0.879±0.022	0.690±
912±0.016	0.868±0.023	0.847±0.026	0.796±
518±0.058	0.713±0.046	0.572±0.063	0.405±
323±0.084	0.237±0.088	0.232±0.089	0.230±
592±0.061	0.702±0.047	0.575±0.063	0.572±
760±0.040	0.922±0.014	0.739±0.042	0.618±
549±0.054	0.938±0.011	0.574±0.063	0.534±
433±0.076	0.555±0.065	0.294±0.085	0.290±
738±0.043	0.819±0.031	0.665±0.052	0.599±
581±0.062	0.729±0.044	0.490±0.071	0.431±
554±0.076	0.494±0.083	0.444±0.088	0.607±
	0.863±0.024	0.747±0.041	0.794±
863±0.024		0.863±0.024	0.688±
747±0.041	0.863±0.024		0.641±
794±0.035	0.688±0.049	0.641±0.055	
1742±0.042	0.821±0.030	0.642±0.055	0.463±
155±0.091	0.275±0.086	0.128±0.093	0.160±
560	0.730	0.604	0.568

s	Bladder	Ovaries	Uterus	
032	0.592±0.061	0.636±0.056	0.468±0.073	
063	0.365±0.084	0.401±0.083	0.276±0.095	
007	0.405±0.081	0.727±0.046	0.436±0.083	
020	0.432±0.076	0.526±0.068	0.647±0.057	
064	0.281±0.086	0.443±0.076	0.392±0.083	
086	0.272±0.087	0.220±0.089	0.331±0.083	
055	0.527±0.068	0.268±0.087	0.502±0.070	
053	0.504±0.070	0.239±0.088	0.599±0.060	
072	0.377±0.080	0.187±0.090	0.472±0.073	
070	0.245±0.088	0.341±0.083	0.407±0.078	
062	0.404±0.078	0.284±0.086	0.401±0.078	
060	0.296±0.085	0.270±0.087	0.322±0.084	
049	0.535±0.080	0.395±0.095	0.348±0.102	
	0.551±0.065	0.666±0.053	0.599±0.060	
065		0.334±0.084	0.624±0.060	
053	0.334±0.084		0.114±0.098	
060	0.624±0.060	0.114±0.098		
082	0.213±0.089	0.281±0.088	0.240±0.094	
048	0.504±0.070	0.712±0.047	0.599±0.063	
071	0.267±0.087	0.293±0.087	0.539±0.071	
	0.407	0.386	0.438	

	Thyroid	Suprarenals	Hypophysis
031	0.786±0.036	0.670±0.052	0.161±0.091
060	0.564±0.065	0.669±0.053	0.231±0.091
022	0.690±0.050	0.613±0.060	0.170±0.094
026	0.796±0.034	0.641±0.055	0.212±0.090
063	0.405±0.078	0.491±0.072	0.081±0.094
089	0.230±0.089	0.376±0.080	0.214±0.090
063	0.572±0.063	0.584±0.062	0.165±0.092
042	0.618±0.058	0.743±0.042	0.048±0.093
063	0.534±0.067	0.608±0.059	0.181±0.090
085	0.290±0.086	0.390±0.079	0.282±0.086
052	0.599±0.060	0.560±0.064	0.293±0.086
071	0.431±0.076	0.478±0.072	0.132±0.092
088	0.607±0.069	0.366±0.095	0.170±0.108
041	0.794±0.035	0.742±0.042	0.155±0.091
024	0.688±0.049	0.821±0.030	0.275±0.086
	0.641±0.055	0.642±0.055	0.128±0.093
055		0.463±0.075	0.160±0.092
055	0.463±0.075		0.124±0.093
093	0.160±0.092	0.124±0.093	
	0.568	0.557	0.177

Uterus	Thyroid	Suprarenals	Hypophysis
468±0.073	0.364±0.081	0.546±0.066	0.430±0.076
276±0.095	0.279±0.090	0.488±0.074	0.458±0.078
336±0.083	0.349±0.086	0.501±0.073	0.411±0.082
647±0.057	0.413±0.078	0.720±0.045	0.522±0.069
392±0.083	0.461±0.074	0.289±0.086	0.110±0.083
331±0.083	0.004±0.094	0.358±0.082	0.510±0.070
502±0.070	0.241±0.088	0.712±0.046	0.494±0.071
399±0.060	0.138±0.092	0.725±0.044	0.637±0.056
472±0.073	0.093±0.093	0.550±0.065	0.322±0.084
507±0.078	0.015±0.094	0.432±0.076	0.344±0.082
501±0.078	0.143±0.092	0.592±0.061	0.226±0.089
522±0.084	0.187±0.090	0.460±0.074	0.339±0.083
548±0.102	0.225±0.107	0.556±0.078	0.367±0.097
499±0.060	0.349±0.082	0.701±0.048	0.486±0.071
524±0.060	0.213±0.089	0.504±0.070	0.267±0.087
514±0.098	0.281±0.088	0.712±0.047	0.293±0.087
	0.240±0.094	0.599±0.063	0.539±0.071
540±0.094		0.332±0.084	0.225±0.090
599±0.063	0.332±0.084		0.508±0.070
539±0.071	0.225±0.090	0.508±0.070	
538	0.240	0.541	0.394

A comparison of the correlations of organ weight and body weight in Table 1 with the correlations between the organ weights from Tables 2 and 3, shows that on the whole, those organs having high correlations with body weight have high average interorgan correlations, and those having low correlations with the body weight likewise have correlations with the other organs which are in the lower range of these correlations. This is better shown in the male cats than in the females. In the males, there is a surprisingly close relationship between the correlations with body weight and those with the other organs; in several cases they have the same relative position in both groups. For example, in the males, the integument has next to the highest correlation in both groups, the heart is third and the kidneys fourth. The length of the digestive tube, the brain and the hypophysis are respectively, 17th, 18th and 19th in both groups of correlations.

It is very easy to understand the position of the correlations with the musculature. It forms nearly a half of the entire body weight, and this readily explains its high correlation with the body weight and with the other organs which themselves are well correlated with the body weight. This average correlation with the other organs is sixth in order of rank and likewise sixth in rank in the correlations with body weight. It might be expected to have even a better correlation with body weight. The heart is third from the highest correlation in all groups except in the average correlation with the other organs in the females, and in this group it ranks first. It is easily understood why the heart, which pumps blood to all of the organs and parts of the body should develop in size in proportion to these parts. The human heart correlated with body weight gives the best correlation reported by Greenwood and Brown (1913). The heart has next to the highest correlation with body weight in the turkey (Latimer, 1927) but in the rat (Jackson, 1913), and the turtle and frog (Latimer, 1920) the correlations between the heart weight and the body weight are in the middle group of correlations which are only moderately good.

The high correlations of the kidneys may be due to their close relationship to all parts of the body, in the elimination of the wastes of all of these parts and organs. The integument covers the body and all of its parts and it must vary with the size of the parts it

covers. The skeleton ranks fifth and seventh in the interorgan and in the body weight correlations, respectively, in the males, and tenth and twelfth, respectively, in the females. It is possible that the more variable amount of fat in the females may account for its lower rank in both groups of female correlations.

At the lower end of the range of correlations are found the brain, the hypophysis and the length of the digestive tube. The brain weight seems to be uniformly independent of the size of the body and of the other organs. In the four groups of correlations, for the two sexes and with body weight and with the other organs, the brain is the lowest in one and next to the lowest in the other three.

The cat is not alone in having low correlations with the brain weight. Pearl (1905) gives the correlations of the brain weight with the stature and with the body weight for three races of mankind. The correlation of brain weight and stature range from 0.183 to 0.349, and the correlations of brain weight and body weight range from 0.167 to 0.226. He states that the correlations with brain weight are not high and that they tend to be a little better in the females. Greenwood and Brown (1913) give the lowest correlations with the weight of the brain. They give the following correlations with the weight of the human brain: with the body weight, 0.25; with the heart weight, 0.08; with the kidney weight, 0.08 and with the weight of the liver, 0.13. In both the dog (Latimer, 1942a) and in the turkey (Latimer, 1927) the brain is not as well correlated with the body weight as is the spinal cord. In both of these last two the correlations with the brain weight are higher than those for the cat.

The hypophysis has the lowest correlations in both male groups and ranks 15th and 18th in the two female groups. The hypophysis is a small gland and yet because of its position and its definite enveloping membrane, its removal was fairly easy and it was done with a good deal of accuracy. As has already been shown (Latimer, 1938b and 1939b), its weight is more variable than the weight of the brain and the spinal cord, but much less variable than the weights of the other endocrines in the cat. It is far less well correlated with the body weight than the other endocrines. Is this due to its multiple function, its small size, or some other factor? The hypophysis of the dog (Latimer, 1941b) has much better correlations with the body weight, brain weight and the weight of the spinal cord.

The length of the digestive tube is 17th in all four groups, or very consistently low in all of its correlations. It is well known that the length of the human small intestine does not vary with the sex, body weight or stature (Jackson and Blount, 1942). In addition to these three organs which are consistently low in their correlations, the thyroid is the lowest in its correlation with the other organs and next to the lowest in its correlation with the body weight in the females. In the males the thyroid is found in the middle group.

Thus we see that there are a few organs in both sexes which have high correlations with body weight and with the other organs, and likewise other organs which are poorly correlated in both sexes, with body weight and with the other organs. In between these two extremes of high and low correlations, there are the weights of the various parts of the digestive system: the weight of the digestive tube, the liver and the pancreas. The eyeballs, the spleen and the lungs are also in this middle group of correlations. The lungs and the spleen are quite variable in their weight and this variability may account for their correlations which are only moderately good. Ahronheim (1937) has studied the liver-spleen ratio in man, and although he gives no correlations, he states that there is a marked interrelationship in the size of these two organs. The correlations for the two organs in the cat is 0.367 in the male and but 0.194 in the female, or in both sexes they are not significantly correlated. Other organs in this middle group are the suprarenals and the male thyroid. We have no explanation for the higher correlation of the eyeballs than that of the brain. It is easy to see that the closer relationship between the spinal cord and the body, in comparison to that with the brain, would naturally account for its higher correlations with body weight and with the other organs. The liver, the pancreas and the suprarenals have more than one function and this multiple function may account for some of their irregularity in the correlations.

The endocrine glands of the albino rat have been studied by Hammett (1925). He gives the correlations of five glands with the body weight and also between the individual glands. He finds the correlations are slightly lower in the females, when correlated with body weight and the interorgan correlations are slightly higher, which agrees with the conditions found in the cat. However, he finds the hypophysis well correlated with body weight. He gives a correlation

of 0.701 for the hypophysis, or the highest of all of the correlations with the body weight. The correlations of all the endocrines with the body weight in the cat average slightly higher than the similar average of the correlations given by Hammett for the rat. The greatest differences are found in the hypophysis, as already stated, and in the correlations of the thyroid, which are quite a good deal higher in the cat. The averages of the correlations between the other endocrine glands are very much alike in the rat and in the cat. Probably the outstanding difference is in the correlations with the hypophysis which are higher in the rat.

In general, organs having high correlations with the body weight, as a rule, have high average correlations with the other organs, and those having low average correlations with the other organs are very apt to have low correlations with the body weight. Between these is a group of organs which are only fairly well correlated with both body weight and with the other organs.

There is a good deal of variation in the correlations of each organ with the other organs as shown in Tables 2 and 3. We have been using the averages, given in the last line of these tables, to get the general variability of these organs but each organ shows quite a range of individual correlations. For example, the male integument has a high average correlation with the other organs and yet the individual correlations show a wide range. Among the best correlations with the integument are: bladder, 0.930; musculature, 0.913; heart, 0.892; etc., and then at the other end of the list is a correlation of only 0.161 with the hypophysis, 0.394 with the brain and 0.437 with the length of the digestive tube. The heart (Table 2) has correlations ranging from a high of 0.912 with the kidney to a low of 0.336 with the brain and 0.212 with the hypophysis. The male heart has only two correlations below 0.5, or those given above. On the other hand if we examine the correlations of the male hypophysis with the other organs, we find no correlation above 0.5. The highest correlation of the hypophysis and any organ is that with the liver and it is not significant, for it is only 0.293. The female hypophysis (Table 3) is much better correlated with the other organs. Its average of 0.394 is 2.2 times the average correlation of 0.177 for the male hypophysis. The female hypophysis has a correlation of 0.5 or above with five other organs. Rasmussen (1934), in a very exhaustive study of the

human hypophysis, finds that the weight of the entire gland is more variable in men than in non-pregnant women. He gives no correlations for the women, but in a study of the male hypophysis (Rasmussen, 1928) he gives a correlation of 0.279 ± 0.060 between the stature and gland weight in normal adult men. The brain of the male, as has been discussed above, is poorly correlated with the body weight and with the other organs. It has only two correlations above 0.5, or with the spinal cord (0.617) and with the skeleton (0.516).

Thus there are low and high correlations in each organ correlated with the other organs. Naturally those having high averages will have more and also higher correlations than those organs having low average correlations.

Correlations and Variability

The correlations of organ weight and body weight and between the various organs have been given, and now the relationship between these correlations and the coefficients of variability of these organs will be shown. The correlations with the body weight, taken from Table 1 and arranged in order of decreasing correlations, for the males and the females, are given in columns one and three of Table 4. The second and fourth columns of this table give the coefficients of variation for the various organs of the males and the females. These are also given in order of decreasing variability. These coefficients of variation are taken from the data given in the earlier papers giving the quantitative data on these cats (see references). Similar groupings have been made for the male and the female average coefficients of correlation with the other organs and the coefficients of variation. These were much like the data shown in Table 4 and so they are not given.

The relationships between these correlations and the coefficients of variation are not as good as was expected. The gonads are the only organs found in the upper third of all four columns and the brain and the length of the digestive tube are the only ones found in the lower third of all four columns. Three organs are above the average of the coefficients in all four columns and they are the gonads, the musculature and the kidneys. In addition to the weight of the brain and the length of the digestive tube, the weights of the liver and the spinal cord are found below the average in all four columns. If

TABLE 4

CORRELATIONS AND VARIABILITY

Males				Females			
Coefficients of correlation with body weight		Coefficients of variation		Coefficients of correlation with body weight		Coefficients of variation	
Musculature	0.978	Testes	55.68	Integument	0.945	Uterus	43.32
Integument	0.974	Spleen	51.56	Musculature	0.917	Spleen	43.17
Heart	0.849	Lungs	45.31	Heart	0.868	Ovaries	40.87
Kidneys	0.837	Kidneys	39.91	Kidney	0.868	Lungs	36.07
Testes	0.828	Integument	31.80	Lungs	0.736	Bladder	30.07
Bladder	0.788	Suprarenals	30.18	Ovaries	0.687	Suprarenals	29.62
Skeleton	0.783	Thyroid	30.01	Pancreas	0.660	Kidneys	27.19
Thyroid	0.780	Musculature	27.93	Spleen	0.616	Thyroid	25.59
Eyeballs	0.756	Heart	27.88	Sp. cord	0.612	Musculature	23.95
Dig. t. wgt.	0.734	Bladder	25.94	Liver	0.591	Heart	22.04
Sp. cord	0.679	Pancreas	25.68	Suprarenals	0.561	Pancreas	21.42
Lungs	0.669	Liver	23.15	Skeleton	0.550	Dig. t. wgt.	19.60
Liver	0.662	Skeleton	21.30	Dig. t. wgt.	0.507	Hypophysis	19.60
Spleen	0.646	Dig. t. wgt.	18.94	Uterus	0.505	Integument	19.39
Suprarenals	0.635	Hypophysis	18.66	Eyeballs	0.505	Liver	19.09
Pancreas	0.498	Sp. cord	17.27	Bladder	0.503	Skeleton	13.33
Dig. t. length	0.429	Eyeballs	10.62	Dig. t. length	0.459	Sp. cord	12.84
Brain	0.370	Brain	8.34	Hypophysis	0.434	Dig. t. length	9.77
Hypophysis	0.189	Dig. t. length	8.23	Thyroid	0.419	Eyeballs	9.57
				Brain	0.317	Brain	7.83

the coefficients of only one sex are compared the relationships are much better.

In many cases it seems that the organs best correlated with body weight have a moderate amount of variability and likewise organs having a great deal of variability are only moderately well correlated with body weight. The best relations seem to be in the case of a few organs with little variability and low correlations with body weight. The brain for example, is at the bottom of both columns in the females and next to the last in both columns in the males. It has been shown above for the cat, and previously for the dog (Latimer, 1942a), that the brain is relatively constant in weight and yet very poorly correlated with body weight. The brain seems to grow to a certain size irrespective of the size attained by the entire body. Other organs are more variable and yet they follow more closely the weight of the entire body, such as the kidneys and the weight of the musculature.

The most striking thing shown in this table is that the organs with the least variability have the lowest coefficients of correlation with the body weight.

Summary

Most of the organs are better correlated with body weight than with body length, and the correlations are somewhat higher on the average in the males than in the females.

There is a good deal of variation in the individual correlations. The integument, the musculature, the heart and the kidneys are the four organs having the best correlations in both sexes and with both body weight and body length. The correlations of the gonads are unexpectedly high. The length of the digestive tube, hypophysis, and the brain have the lowest correlations.

In general, organs having high correlations with body weight, have high average correlations with the other organs and similarly, those having low correlations with the body weight have low average correlations with the other organs. In between these two groups is a group only moderately well correlated with body weight and with the other organs.

Those organs having low coefficients of variability have low coefficients of correlation with body weight and with the other organ weights. In many cases it seems that organs best correlated with

body weight have only a moderate amount of variability, and likewise organs having a great deal of variability are only moderately well correlated with body weight.

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